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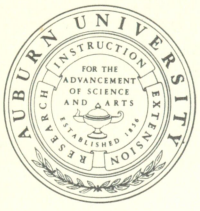

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THE HILLABEE SILL

INTRODUCTION

STATEMENT OF PROBLEM

The large triangular wedge of metamorphic and igneous rocks underlying much of eastern Alabama is often referred to as the Crystalline area. It constitutes the southernmost exposure of rocks of the Piedmont division of the Appalachian system. In the western part of this area are two extrusive overthrust sheets. The westernmost of these contains the low grade metasediments of the Talladega series; within the eastern sheet are the middle grade schists of the Ashland formation. Along the Whitestone fault—the major thrust fault separating these two great sheets—occur the low grade schists of the metamorphosed Hillabee sill.

The object of the present report is to describe the structure, petrography, and age of the Hillabee sill. Previous work in the western part of the Crystalline area had resulted in a generalized (and locally detailed) mapping of the sill. Several lithologically different phases had been mentioned or briefly described but these had not been mapped. The nature of the original intrusive rock and its manner of intrusion had not been clearly defined; details of its subsequent metamorphism were almost completely lacking. There were, furthermore, several outstanding differences of opinion regarding the age of the sill, for the Hillabee schists had, by a kind of spatial coincidence, become involved in Ocoee-Talladega-Erin age controversy. The problem resolved itself, therefore, into the relating of the intrusion, metamorphism, and deformation of the sill to the age, petrologic and diastrophic history of the intruded rocks—the Talladega series and the Ashland Mica Schist.

GEOGRAPHIC LOCATION

The 350 square mile area covered by the present report lies adjacent to the western margin of the Crystalline area and includes portions of eastern Talladega, western Clay, northern Coosa, and northwestern Tallapoosa counties, Alabama. The location and extent of the Hillabee map area are shown on the index map, Figure 1.

As reference points, it may be noted that this area lies generally between the towns of Talladega, Ashland, Sylacauga, and Goodwater. The region is crossed by several primary roads,

which connect the towns mentioned, and has, in addition, a well developed net of secondary roads. The Central of Georgia Railway extends across the southern extremity of the area from Sylacauga through Hollins and Pine Grove to Goodwater. In the north, the Atlanta, Birmingham, and Coast Railway follows a circuitions route from Talladega eastward through Chandler Springs, Clairmont Springs, Erin, and Pyriton.

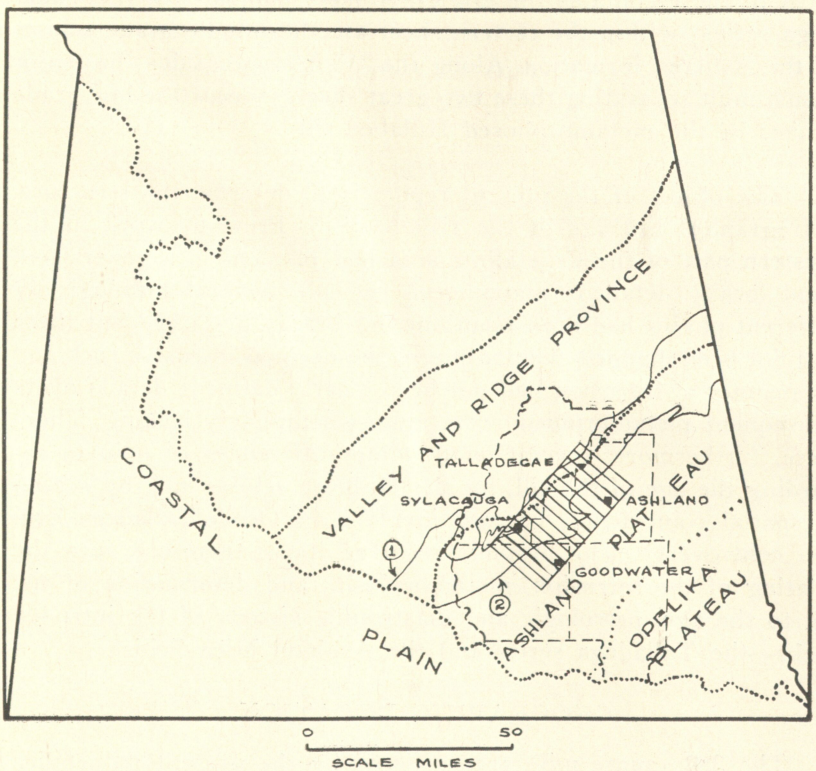

FIGURE 1

Figure 1. Index-map of northern Alabama showing location of the Hillabee map area with relation to political and physiographic subdivisions of Alabama. The northern tier of counties outlined are, from west to east, Talladega and Clay; the southern tier, reading in the same direction, are Coosa and Tallapoosa. Number (1) indicates the trace of the Cartersville fault; number (2), the trace of the Whitestone fault. That portion of Alabama lying southeast of the Cartersville fault and north of the Coastal Plain constitutes the Crystalline area.

PHYSIOGRAPHIC SETTING

The Hillabee map area lies wholly within the Ashland Plateau district of the Piedmont uplands. As defined by Fenneman[1] the western boundary of this plateau district lies at the western base of the Talladega Mountains. At the latitude of Porter Gap, near Chandler Springs, the boundary shifts southwestward to a position near the Coosa River. Here it is defined by the western margin of the belt of Talladega slates and phyllites which it follows southward to the Coastal Plain.

The Ashland Plateau has been described by Adams[2] as the mountainous portion of the Piedmont. This characterization is especially applicable to the western portion of the plateau. Here the Piedmont peneplain, probably at best only imperfectly developed, has been upwarped and strongly dissected. Differential etching of metamorphic and igneous rocks of several types and degrees of resistance has imparted to the region a pronounced ridge and valley topography of mountainous proportions. This surface configuration has a general northeast-southwest trend and is well shown throughout the Hillabee map area.

Less dissected portions of the Ashland Plateau are limited to the area underlain by rocks of the Ashland formation and are best developed near Ashland, Clay County. Prevailing summit levels here are slightly more than 1100 feet above sea level. About 15 miles south and slightly east of Ashland the summit levels are 100 to 150 feet lower. Streams are generally incised 50 to 300 feet below summit levels and the entire area may be briefly characterized as one submaturely dissected.[3]

The rolling plateau surface is marked, especially along its northwestern margin, by low discontinuous ridges developed on more resistant facies of the Ashland schists. Among these are

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[1]Fenneman, N.M.—Physiography of Eastern United States, McGraw-Hill, 1938, Plate III.

[2]Adams, G. I., Butts, C., Stephenson, L. W., and Cook, W.—Geology of Alabama, Spec. Rept. 14, Geol. Surv. of Ala., 1926, pp. 26-27.

[3]Topographic data from Topographic Map of the U. S., U. S. G. S., Ashland Sheet (1891) and Talladega Sheet (1891).

Shinbone Ridge, Candutchkee Ridge, and Hillabee Ridge, whose summits reach elevations of 1300 to 1600 feet. They are thus 200 to 500 feet higher than the plateau surface but may rise as much as 600 feet above adjacent valley floors.

Prevailing drainage of the less dissected Ashland Plateau is eastward and southward by way of the Tallapoosa River and its numerous tributaries.

The western edge of the well defined plateau is formed by a ragged but persistent escarpment by which the surface is lowered 150 to 200 feet to a narrow valley trend developed on the less resistant schists of the Hillabee sill and on certain slates and phyllites of the Talladega series. The elevation of this valley belt ranges from 1100 feet in the north, where the escarpment is indistinct to about 800 feet near Hollins. The valley is drained by Ketchepedrakee Creek, Talladega Creek, East and West Forks of Hatchet Creek, and Weogufka Creek. Tributaries of these streams have effected a considerable dissection of the Ashland escarpment.

From the Hillabee valley belt westward the plateau has been largely destroyed and is recorded only by a few isolated summits. The most prominent physiographic feature west of the Ashland escarpment—and indeed the most conspicuous surface feature of the entire area—is Talladega Rebecca Mountain—the monoclinal ridge maintained by the Cheaha quartzite member of the Talladega series. A few miles north of the Hillabee map area this ridge forms Cheaha Mountain, the highest point in the state. In the tangle of ridges north of Pyriton, summits are more than 2100 feet above sea level. Southeastward from this point to Bull Gap high points of 1800 to 1900 feet are common. South of Bull Gap, however, the ridge narrows and declines in elevation until it finally disappears northwest of Hollins.

The phyllites and slates that lie west of Talladega-Rebecca Mountain form a rather fine textured, hackly topography with an average elevation of some 800 feet. This topographic character persists westward to the boundary of the Talladega thrust block where a low, dissected, but clearly marked escarpment separates it from the long strike valleys and ridges of the Paleozoic areas.

PREVIOUS WORK

Probably the first reference to the Hillabee sill occurs in one of the early reports of the Alabama Geological Survey. In 1858, Toumey, the first State Geologist of Alabama, in discussing the search for copper in the vicinity of Chulafinee, wrote, "From Randal's Bridge, along the Fishhead Creek, a fine strip of hornblende rock is found, extending into the Hillabee Country, where it is so altered as to resemble a light green basalt, retaining, however, its stratified structure."[4]

As late as 1874 it is evident that the distinction of the Hillabee sill from the associated metasediments and its origin from the metamorphism of an intrusive igneous rock had not been recognized. Smith, who succeeded Toumey as State Geologist, characterized the "Ocoee" group as "a series of semi-metamorphic strata between 15,000 and 20,000 feet in thickness—composed of greenish gray hydro-mica slates, (talcoid slates, nacreous argillites, talcose slates,) passing upwards into a conglomerate—succeeded by thick beds of quartzite, alternating with greenish chlorite schists."[5]. It is probable that the Hillabee was regarded at this time as one of the upper "greenish chlorite schists."

In the years that followed Smith's appointment as State Geologist, investigation of the metamorphosed terrain of eastern Alabama was accelerated by widespread interest in the search for gold, copper, silver, graphite and other mineral resources. From 1873 until 1878 Smith engaged in geological reconnaissance in the Crystalline area and later, at his invitation, several geologists of note from other sections of the country visited the region. That these activities were of great importance in the sharper delineation of geological features of the region is evident in later reports by Smith in the published records of certain of his visitors. In 1885, for example, Hitchcock recognized at Chandler Springs the development "of a heavy greenith chlorite schist similar to the green rock east of the Green Mountains in Canada, Vermont and Mass-

[4]Touney, M.—Second Biennial Report on the Geology of Alabama, p. 71, 1858.

[5]Smith, E. A.—Report of Progress for 1874, Geol. Surv. of Ala., 1874, p. 21.

[6]Hitchcock, C. H.—The Crystalline Rocks of Alabama, Am. Jour. Sci., Vol. 130, 1885, pp. 278-283.

achusetts"[9] and believed it to be of Huronion age. This schist he thought was infolded between the "Ocoee" and the overlying "feldspathic mica schist, or—imperfect gneiss."

Phillips, in 1892, mentioned the green schist exposed in the vicinity of Millerville, Iwane, and Hillabee.[7] It was in 1896, however, that the first reasonably detailed characterizations of the Hillabee appeared. In this year was published a report on the Upper Gold Belt of Alabama[8] in which Smith referred to the "chlorite-epidote schists, actinolite-epidote schists, chlorite schists" as the Hillabee schist, from a typical locality, and regarded all as the "result of alteration of some basic eruptive rock."[9] He described the formation, in part as follows: "In the fresh condition these rocks are of light green color and are rather massive in structure, and very tough, but on weathering they turn into greenish yellow slates much stained with iron, and then bear a striking resemblance to some of the Talladega slates with which they are in immediate contact... The highly schistose and slaty varieties may be seen about Hillabee or Millerville, in Clay County, and particularly at Monroe's Mill close by. The varieties resembling siliceous conglomerate abound along the road leading from Millerville toward Hatchet Creek post office, and especially along the flanks of McGhee Mountain."[10].

Smith's work on the crystalline rocks of Alabama was supplemented, from 1901 to 1904, by that of McCalley, whose death in 1904 greatly delayed publication of a comprehensive report on the geology of this region. In 1916, Prouty was assigned the task of

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[7]Phillips, W. B.—A Preliminary Report on a part of the Lower Gold Belt of Alabama, in the Counties of Chilton, Coosa, and Tallapoosa, Bull. No. 3, Geol. Surv. Ala., 1892.

[8]Bull. No. 5, Geol. Surv. Ala., 1896. Part 1—A Preliminary Report on the Upper Gold Belt of Alabama, in the Counties of Cleburne, Randolph, Clay, Talladega, Elmore, Coosa, and Tallapoosa by Brewer, W. M. Part II—Supplementary Notes of the Most Important Varieties of the Metamorphic or Crystalline Rocks of Alabama, their Composition, Distribution, Structure, and Microscopic Characters by Smith, E. A., Hawes, G. W., Clements, J. M. and Brooks A. H.

[9]Idem p. 123.

[10]Idem, p. 121-122.

preparing a detailed geological report and map of Clay County, Alabama. His report, published in 1923, embodied the results of his own field work and research plus those of Smith and McCalley.[11] Prouty's map and report were a valuable contribution to the knowledge of the geology of the crystalline area. For the first time the pattern of the Hillabee sill was portrayed accurately and on a reasonably scaled map, and the age, structure, and petrography of the formation were discussed in some detail.

In more recent years, several reports by Adams contain descriptions of the Hillabee sill. In 1926, as a result of some twenty years work, a comprehensive report on the Geology of Alabama and a geological map of the state were published.[12] In this work Adams revised the mapping and summarized the geological features of the Hillabee. The formation is discussed in several later papers as, for example, in his report on the gold deposits of Alabama.[13]

Under Adams' supervision, the reconnaissance mapping of the crystalline area was completed by 1933 and, in that year, his conclusions were published in a short paper.[14] The Hillabee sill, referred to in this latter paper as the "Hillabee Chlorite Schist" is described as follows: "This chlorite schist is interpreted as a sill of altered igneous rock which was intruded along, and apparently lubricated, a great thrust plane. It extends with some short interruptions for about 100 miles and lies between the Talladega series and the Ashland mica schist which has overridden the Talladega from the southeast. In its most expanded area it is probably more than 500 feet thick. Coarse grained specimens from it show the structure and minerals of a diorite."[15]

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[11]Prouty, W. F.—Geology and Mineral Resources of Clay County with special reference to the Graphite Industry, County Report No. 1, Geol. Surv. Ala., 1923.

[12]Adams, G. I., Butts, C., Stephenson, L. W., Cooke, W.—Geology of Alabama, Spec. Rept. No. 14, Geol. Surv. Ala., 1926; Stose, G. W.—Geological Map of Alabama, U. S G S., 1926.

[13]Adams, G. I.—Gold Deposits of Alabama and Occurrences of Copper, Pyrite, Arsenic, and Tin, Bull. 40, Geol. Surv. of Ala., 1930.

[14]Adams, G. I.—General Geology of the Crystallines of Alabama Jour. Geol., Vol. 41 pp. 159-173 1933.

[15]Idem, p. 164.

Many other workers have contributed to the geological knowledge of the Hillabee sill and associated metamorphic rocks of Alabama. To them reference will be made in the following sections.

PRESENT INVESTIGATION

The attention of the writer was first directed toward the Hillabee sill in 1938 by Dr. S. J. Lloyd, Assistant State Geologist of Alabama, and Dr. T. G. Andrews, Professor of Geology in the University of Alabama. Since practically all previous work on this metamorphosed intrusive had been of reconnaissance nature, a detailed structural and petrographical inquiry was regarded as a fruitful field of investigation.

Field work was begun in 1940 and, in the summers of this and the following year, six months were spent in Talladega, Clay, Tallapoosa, and Coosa Counties, Alabama. Two additional weeks were devoted to field work in July, 1946.

Considerable initial difficulty was encountered in securing adequate base maps for geological mapping. During the first season, county road maps at a scale of 1 : 62,000 were utilized. These were supplemented in critical areas by compass and pace traverses. In 1941, a planimetric base map covering a major part of the area was secured from the Forest Service, U. S. Department of Agriculture. In the latter part of the summer, complete aerial photographic coverage at a scale of 1 : 20,000 was obtained through various agencies of the U. S. Department of Agriculture.

Laboratory investigations were begun at the University of Cincinnati in the fall of 1941 but were interrupted upon the entrance of the United States into World War II. These were not resumed until February, 1946.

For the final geological map, published herewith, a polyconic projection at a scale of 1 : 31,250 was constructed. Township, range, and section boundaries were transferred to this base from the Forest Service map and county road maps. Culture, political boundaries, and drainage were added from existing maps and from the aerial photographs. All geological data appearing on the map were transferred thereto by radial line triangulation from aerial photographs.

ACKNOWLEDGEMENTS

Field work in Alabama in 1940 and 1941 was made possible through the cooperation of the Geological Survey of Alabama. During these two field seasons, Dr. Stewart J. Lloyd, Acting State Geologist during the military leave of absence of Dr. Walter B. Jones, was most helpful in the administrative aspects of the investigation. Field expenses were defrayed by the Geological Survey of Alabama which, in addition, paid for the thin sections and purchased approximately one half of the aerial photographic coverage. Dr. Jones kindly provided certain of the illustrative material and arranged for the publication of the final report.

Drs. T. G. Andrews and E. F. Richards of the Department of Geology, University of Alabama, loaned various items of field equipment and discussed with the author several phases of the problems encountered in studying the Hillabee sill.

It is a pleasure to acknowledge the indebtedness of the author to the staff of the Department of Geology and Geography of the University of Cincinnati. Many helpful suggestions have been received from Drs. John L. Rich, George B. Barbour, Otto C. von Schlichten, Wayne M. Felts, Gorden Rittenhouse, and Aureal T. Cross. Professor von Schlichten prepared the photomicrographs and Drs. Rich and Cross photographed the fossil "crinoid stem" found in the Cheaha quartzite.

To each of these men the writer wishes to express his wholehearted thanks for making possible the satisfactory completion of this investigation.

The Production and Marketing Administration of the U. S. Department of Agriculture has given permission to reproduce the aerial photograph of the area near Erin, Clay County.

FORMATION DESCRIPTIONS

ASHLAND MICA SCHIST

The name "Ashland Mica Schist" was first applied by Smith and McCalley[16] in 1904 to a series of schists widely developed in

[16]Smith, E. A. and McCalley, H.—Index to the Mineral Resources of Alabama, Bull. 9, Geol. Surv. of Ala., 1904, p. 8.

Clay and Coosa Counties and exposed typically near Ashland, Clay County. As used in this report the name includes those schists previously designated as Ashland Mica Schist and some of the rocks heretofore regarded as "altered Talladega" or as the Wedowee formation.

Distribution of the schists within the Hillabee map area is shown on the accompanying geologic map. The western boundary of the formation is the trace of the Whitestone fault—one of the major overthrusts of the southern Appalachians. Along this fault the Ashland schists are in contact with the metamorphosed rocks of the Hillabee sill or, where these are absent, with the slates and phyllites of the Talladega series.

The Ashland formation is composed principally of medium grade or mesozone mica schists. The most common types are quartz-muscovite schist and quartz-biotite schist, both of which are locally garnetiferous. Gradations between these types occur and locally they alternate in stratigraphic sequence. The muscovite facies seems to be somewhat more widely developed than the biotite facies. In Clay and Coosa Counties the quartz-muscovite schists are strongly graphitic at certain horizons and have been mined for flake graphite.[17] The graphitic rocks are, for the most part, limited to a belt one to five miles wide lying from three to six miles east of the Whitestone fault. The belt extends generally southwestward across Clay and Coosa Counties except for a gap of about eleven miles in southwestern Clay County.

Many igneous intrusives occur in the Ashland Mica Schist. Some of these are border injections clearly related to the Hillabee sill, and will be described later. Others, probably affiliated with the Pinkneyville quartz-diorite complex, are small sill-like bodies of aplite, pegmatite, and granitic rocks, most of which appear to be essentially unmetamorphosed.[18] A third set of narrow and discontinuous, but widely distributed, sills are older than the metamor-

[17]Prouty, W. F.—Geology and Mineral Resources of Clay County, County Rept. No. 1, Geol. Surv. of Ala., 1923, pp. 91-131.

[18]Gault, H. R.—Petrography, Structures, and Petrofabrics of the Pinkneyville Quartz Diorite, Alabama, Bull. G. S. A., Vol. 56, 1945, pp. 181-246; Hunter, F. R.—Geology of the Alabama Tin Belt, Bull. 54, Geol. Surv. of Ala., 1944, 61 pp.

phism of the Ashland schists and have been involved in it. These rocks, where not too deeply weathered, are clearly distinguishable from the adjacent meta-sediments. Megascopically, they are dark gray, strongly schistose, and often thinly laminated hornblende schists and gneisses.

PETROGRAPHY

Meta-sediments: The muscovite schists are typically strongly schistose, medium-grained rocks composed essentially of laths and porphyroblasts of muscovite set in a schistose quartz or quartz-feldspar mosaic. Garnet porphyroblasts are present locally and frequently are abundant. Accessories include graphite, magnetite, biotite, plagioclase, rutile, epidote. Tourmaline and pyrite are late introduced minerals. (Figure 2A.)

With decrease in the amount of muscovite present, and a corresponding increase in the amount of biotite, there is a transition to the biotite schist facies of the Ashland formation. These rocks are, for the most part, entirely similar structurally, texturally, and mineralogically to the muscovite schists except that graphite is usually absent or present only in small amounts.

A rather unusual type of biotite bearing rock was noted near Spring Hill where a small exposure of medium grained garnetiferous biotite gneiss occurs. Quartz and a little andesine form an almost equigranular granoblastic mosaic that is transected by rhomboidal shear planes along which the fabric is mortared to schistose. Large rutilated biotites and small muscovite laths in the mosaic and along the shears are bent, broken, and shredded. Plagioclases show both albite and pericline twinning and are locally altered to fine-grained clinozoisite. The presence of large clots of small, diversely oriented muscovite flakes probably record the presence in the original rock of orthoclase. The most unusual feature of this rock is the occurance in unsheared augen of sieve garnets up to one centimeter long. Tourmaline, graphite, zircon, apatite, magnetite are accessories.

Schists of either type have locally a strongly developed equigranular quartz mosaic with intricately sutured intergranular contacts. The more characteristic structure is one of elongate grains arranged in a schistose mosaic. Micas, both muscovite and

biotite, are late in the crystalloblastic series and occur as subidioblastic laths and as porphyroblasts poikiloblastic to quartz, feldspar and most of the accessories. Garnet generally is last in crystalloblastic sequence and its force of crystallization has usually deformed the previously formed schistosity defined by the micas and elongate quartz grains. The development of garnet is, locally at least, overlapped by the formation of biotite and quartz for these minerals are to be found recrystallized in the low pressure areas lying at the sides of garnets.

Kyanite, sillimanite, and chloritoid have been reported to occur in the schists.[19] None of these species was noted in the sections examined.

All of the schists examined microscopically were sheared. The least deformed rock—a quartz-biotite granulite with silicic plagioclase and a little muscoviete, magnetite, and pyrite—showed a minor amount of fracturing and straining of the quartz grains and a bending and opening of a few of the mica cleavages. More commonly shearing has caused an incomplete granulation of feldspar and quartz, and a bending and partial shredding of the micas. This stage is marked by the development of shear planes which tend to bend around the garnets. Garnet prophyrobasts commonly are fractured but are little rotated or strewn. The schists at this stage of cataclasis have mortared to microbrecciated fabric with flaser and porphyroclasts of incompletely granulated rock and mineral grains. The most advanced degree of clastic deformation is recorded in the mylonites and phyllite mylonites—rocks that have been almost completely granulated. The fabric of these rocks is a strongly schistose microbreccia of quartz, feldspar and accessories with minutely shredded micas. A few relicts of the original rock that have escaped complete cataclasis are present as flaser. Garnet-quartz flaser are especially common. Megascopically, these strongly sheared medium grade schists are almost indistinguishable from low grade phyllites but, where garnet and biotite can be detected, the hypothesis of the origin of such rocks by the extreme cataclasis of the schists is incontestable.

Although cataclasis of the Ashland has resulted in striking structural and textural alteration, mineralogical transformations

[19]Hunter, F. R.—op. cit., pp. 16, 18-19.

have been quantitatively less important. The only changes observed have been the incomplete and local chloritization of biotite and garnet.

Neither tourmaline nor pyrite has been involved in the cataclasis of the Ashland schists. Light yellowish brown tourmaline porphyroblasts are present in some sections examined and are poikiloblastic to quartz and graphite. These, like garnet, have deformed previously existing structures but show no sign of fracturing or straining (Figure 2B.) Similarly, pyrite occurs as small unbroken idioblastic to subidioblastic grains. Both of these minerals are interpreted as due to post-shearing mineralization of the schists.

Meta-igneous rocks: The metamorphosed sills in the Ashland Mica Schist are of thinly foliated and strongly schistose fabric. A specimen representative of the most common sill rock is a quartz-andesine-hornblende schist and contains hornblende (50%), quartz (25%), andesine (20%), zoisite 2%), pyrite (2%), garnet (1%). Quartz and plagioclase form an equigranular granoblastic mosaic that is poorly schistose and locally mortared. Hornblende is in parallel elongate grains poikiloblastic to quartz and plagioclase. Zoisite occurs as a fine grained xenoblastic alteration of plagioclase and also in larger idioblastic grains intimately recrystallized with the amphibole as is garnet. Hornblende (or pargasite) may make as much as 73% of the rock and quartz may be absent. Biotite may be present with, and altered from, amphibole. Epidote may be present to the exclusion of zoisite. Accessories include titanite, apatite, magnetite.

METAMORPHISM.

The bulk of the Ashland schists are interpreted as having been derived by normal regional metamorphism of a medium grade from a series of impure arenaceous sediments. The principal variations in the original sediments were differences in quantity of quartz, clastic feldspars (both orthoclase and plagioclase), the micaceous constituents (chloritic and sericitic materials), and local concentrations of carbonaceous matter.

The minerals indicative of mesozone conditions—biotite and garnet—are widely distributed in the schists. Even where these

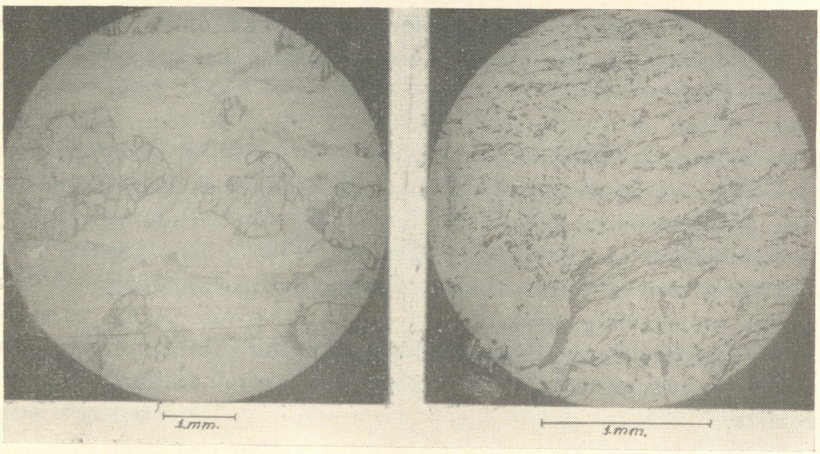

FIGURE 2A FIGURE 2B

Figure 2A. Ashland formation. Garnetiferous quartz-muscovite-biotite schist. Garnet porphyroblasts are poikiloblastic to quartz, graphite, biotite and occur in a schistose quartz mosiac. Some biotite is earlier than garnet and is deformed by force of crystallization of garnet; other biotite appears to be later as it occurs in fractures or in low pressure areas at sides of porphyroblasts. Fabric is sheared —a post-metamorphic strain—as shown by breaking and strewing of micas, fracturing of garnets. (Locality: NE ¼, Section 3, T, 20S., R. 7E.)

Figure 2B. Ashland formation. Tourmalinized graphitic quartz-muscovite schist. Tourmaline porphyroblasts include quartz and graphite. Note poorly developed herringbone pattern of muscovite —probably a relief structure of the phyllite grade. (Locality: S Central ½, T.22S., R. 7E.)

minerals are absent, textural and structural similarities of the schists attest to their universal middle grade rank. However, local high grade zones may occur near some later intrusives.

Bedding is not apparent in thin sections, but field relations suggest that it is everywhere parallel to the schistosity. The only relict of an early stage of metamorphic history is a vague herringbone pattern formed by muscovite flakes in a schistose quartz mosaic. This may record a shear pattern developed during the phyllite stage. (Figure 2B.)

In distinction to the meta-sedimentary schists, the metamorphosed sills show a very different mineral assemblage. Hornblende and garnet are constituents indicative of middle grade conditions. Although a little biotite is found, this mineral is believed to represent a retrogression of amphibole. Texturally and structurally these hornblende schists (or gneisses, where foliated) are similar to the muscovite and biotite schists. They are interpreted as derived from intermediate igneous rocks of dioritic composition.

POST-METAMORPHIC EFFECTS.

In practically all exposures the Ashland schists appear to have been somewhat sheared and in certain areas such deformation has been extreme. The intensity of shearing generally increases as the overthrust western edge of the schists is approached but extreme cataclasis is encountered as well along minor thrusts within the Ashland formation. Phyllite mylonites are especially well developed in a broad northeast-southwest zone passing through Elias and immediately south of Millerville. Rocks near the Whitestone fault are not everywhere strongly sheared, however. For example, a quartz biotite granulite occurring within 350 horizontal feet of this sole fault shows only a partial straining and fracturing of quartz grains and a bending and opening of a few of the mica cleavages.

Although shearing of the Ashland schists has resulted in more or less profound structural and textural alterations, the cataclasis has been attended by few mineralogical changes. Of the latter, the most notable has been an incipient chloritization of biotite and garnet. Usually replacement has been peripheral and partial and has occurred only where shearing stress has been strong. Changes of this type are usually regarded as of retrograde nature. Conditions promoting them appear to involve moderate to strong cataclasis and the addition of considerable water.

Both metamorphism and the later shearing were followed by the emplacement of the granitic intrusives mentioned previously. Near these sills and, more prominently, near the main mass of the Pinkneyville complex, the schists have been tourmalinized. Apatite and pyrite are late introduced minerals whose source is unknown. In addition to these materials, quartz veins are prominent and widespread in the area of Ashland schists.

STRUCTURE.

The generally southeastward dipping monoclinal schists of the Ashland formation are thrust northwestward over the low grade metamorphics of the Talladega series forming an extensive deck of unknown thickness. The Whitestone fault, along which the major thrusting occurred, is not confined to a single stratigraphic horizon of the schists for any considerable distance. It is found to transect bedding and schistosity at low angles. The stratigraphically lowest schists are exposed at the western extremity of the northern lobate projection in Clay County and also, farther south, in Coosa County. Between these two areas and farther north, toward Pyriton, stratigraphically higher schists lie adjacent to the fault.

The regional structure of the Ashland formation is marked by the topographic pattern of certain more resistant facies of the schists. For example, in Clay County, the quartzose graphitic schists form Shinbone-Candutchkee Ridge which extends in a southwesterly direction from near Flatrock to section 30, T. 20S., R. 7E., at which point it curves southeastward until it abuts against the Hillabee schists in section 7, T. 21S., R. 7E. Near its southern extremity Shinbone-Candutchkee Ridge is paralleled by a series of discontinuous subsidiary ridges, probably due to a repetition of the resistant schists by faulting. Schistosity and bedding, which are parallel, dip in easterly directions normal to the trend of the ridges. In Coosa County, similar and perhaps stratigraphically equivalent ridge-forming graphitic schists strike northeastward and dip toward the southeast.

Gentle to complex folding and minor thrusting are of common occurrence throughout the thrust block but such deformation has been especially intense in the schists adjacent to the Whitestone fault. In this border zone the rocks have undergone a megabrecciation accompanied by close folding and profound shearing. Differential movement and the rotation of individual fault blocks have resulted in striking structural discordances.

The structures of the Ashland Mica Schist are of interest herein primarily as they are related to the intrusion and metamorphism of the Hillabee sill. Attention is directed in the following sections, therefore, to those structures adjacent to the Whitestone fault, along which the sill was intruded.

Pyriton to Millerville: From the western extremity of the northern lobate area of Ashland schists, near Chambers Spring, to Pyriton, border structures are relatively uncomplicated. The plane of the Whitestone fault rises generally in the schist section so that the schists strike into the trace of the fault at angles of 15 to 30 degrees. Locally, these two structural elements are parallel, as at Pyriton where the fault dips southeastward at an angle of 35 degrees. Several diagonal faults occur in the schists of this area but their precise attitude and location are not known because of a paucity of exposures. A considerable number of essentially interstratal thrusts are known to be present near Pyriton. Where these are associated with folding considerable repetition of strata is probable. (Figure 3A and 3B.)

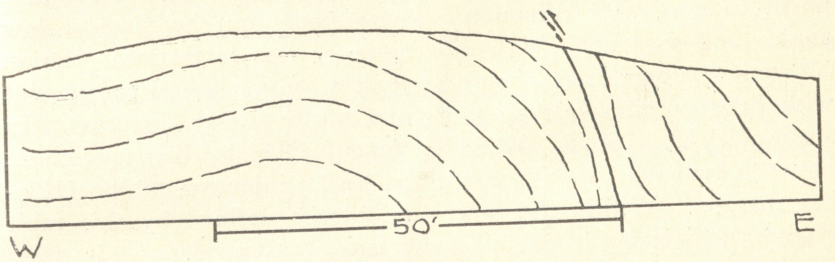

FIGURE 3A

Figure 3A. Structure of Ashland schists exposed in cut of the Atlanta, Birmingham, and Coast R. R. east of Pyriton. Dashed lines indicate attitude of bedding and schistosity. (Locality' NE ¼, section 20, T, 19S., R. 8E.)

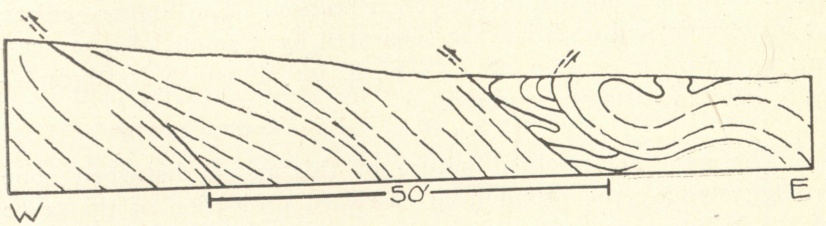

FIGURE 3B

Figure 3B. Ashland schists exposed in cut a short distance west of rocks shown in Figure 3A. Such close folding and thrusting of the schists is generally unrecognized unless good, continuous exposures are present. (Locality: NE ¼, section 20, T. 19S., R. 8E.)

Schists adjacent to the major thrust have been strongly sheared and locally reduced to the rank of phyllite mylonite. In section 24, T. 19S, R. 7E, a thickness of approximately 300 feet of phyllite mylonites having a pronounced rhombodial shear pattern was mapped and described by Prouty[20] as Talladega phyllites lying between the Hillabee sill and the Ashland Mica Schist.

Southeastward from Chambers Spring toward Millerville, the Whitestone thrust rises high into the schist section. As in the area further north, the schists generally strike at considerable angles into the trace of the thrust.

Marginal faults are numerous. A prominent set strikes in a north to northwest direction. These faults cut bedding at low angles and pass northward into more or less interstratal planes, Movement along these planes has had a strong lateral component with beds on the west moving in a southeasterly direction. In section 12, T. 21S., R. 6E, an opening formed by this movement between two fault blocks was filled by an injection of the Hillabee magma. Within the individual blocks defined by this fault system, schistosity is curved persistently eastward.

Near Millerville the north-northwest faults are supplemented by several northeast trending faults, and folding of the schists is more intense.

Millerville to Hollins: Between the northern lobe of schists in Clay County and the southern lobe in Coosa County, the Whitestone fault rises high into the schist section. The higher schists, at Millerville and at Elias, are separated by a small lobe, projecting westward to section 32, T. 21S., R. 6E, in which stratigraphically lower schists are exposed.

The general anticlinal nature of this much disturbed zone is suggested by the pronounced eastward projection of the trace of the Whitestone fault and is demonstrated by eastward bending of bedding and schistosity in adjacent portions of the northern and southern lobes. The small western extension of schists

[20]Prouty, W. F.—Geology and Mineral Resources of Clay County, County Rept. No. 1, Geol. Surv. of Ala., 1923, pp. 24-25.

included within the major anticlinal area has been severely compressed with resulting tight northeasterly trending folds and intricate faulting. This much deformed zone is terminated on the east by a belt of profoundly sheared rocks one to two miles wide and extending from the northwestern corner of Tallapoosa County through Elias and passing slightly southeast of Millerville. Within this belt the schists have been reduced to the rank of phyllite mylonites. A rhomboidal shear pattern is well developed and shear planes over wide areas are wrinkled and corrugated. Shear planes and axial planes of small folds have a prevailing northeasterly strike and dip steeply northwest or stand vertically. Schistosity strikes northeastward and dips generally southeastward at steep angles. This belt of phyllite mylonites was mapped as "Altered Talladega" by Prouty[21] and by Adams[22] as the Wedowee formation.

Coosa County: The regional southeasterly dipping monocline is comparatively little deformed in this area. Border zones, however, are locally faulted and were injected by the Hillabee magma as in section 9, T. 24N., R. 19E.

The long narrow tongue of Hillabee schist extending southeastward in section 6, T. 24N., R. 20E., is thought to have been exposed by erosion through the Ashland thrust plate. Locally at least, the Whitestone thrust plane is interpreted as dipping southeastward at very low angles.

AGE OF THE ASHLAND MICA SCHIST.

No fossils have been found in the Ashland formation and its age is therefore largely a matter of conjecture. The only evidence of organic remains is graphite present in certain of the schists. The structural deformation of the Ashland formation can be related to the disturbances of the Applachian Revolution but was preceded by a profound metamorphism of the original Ashland sediments. The U. S. Geological Survey regards the Ashland Mica Schist as pre-Cambrian.[23]

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[21]Prouty, W. F.—op. cit., pp. 46-51.

[22]Adams, G. I., Butts, C., Stephenson, L. W., Cooke, W.—op. cit., pp. 36-38.

[23]Wilmarth, M. G.—Lexicon of Geologic Names of the United States, U. S. G. S., Bull. 896, Part I, 1938, p. 81.

TALLADEGA SERIES

This series of low grade metamorphic rocks was designated the "Talladega (Ocoee) group" by Smith in 1888 from typical exposures along Talladega Creek in Talladega County.[24] In Alabama the series forms a northeast-southwest trending belt 8 to 22 miles in width. It is separated from the Ashland Mica Schist and the Hillabee sill by the Whitestone fault and is bounded on the northwest by the Cartersville thrust. (Figure 1.) According to Butts[25] the Talladega series aggregates a thickness of 30,000 feet of slates and sericite phyllites with interbedded conglomerates, sandstones, limestones, marbles, dolomites, cherts, graphitic phyllites, and quartz schists.

In the Hillabee map area only the upper part of the Talladega series is exposed. For mapping and description, these strata are divided into three units—the Cheaha quartzite, the Erin slate, and a group of quarzites, phyllites, and slates lying below, between, and above these two members. Lateral variations in thickness and character are imperfectly known. (Figure 4.)

CHEAHA QUARTZITE MEMBER

This persistent ridge-making quartzite, referred to by Butts[26] as the "Cheaha sandstone member," forms Talladega-Rebecca Mountain. The maximum thickness of the quartzites is approximately 2600 feet. Variations in thickness are caused in part by folding and thrust faulting. The quartzites form a continuous exposure from the northern limit of the Hillabee map area to a point about one and one-half miles northwest of Hollins. In addition, the Cheaha quartzite forms Chestnut Ridge—a southward extension of Talladega Mountain north of Pyriton—and a small isolated ridge in section 2, T. 20S., R. 6E.

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[24]Smith, E. A.—Report of Progress 1884-1888, Geol. Surv. of Ala., Geological Map of Alabama, 1888.

[25]Adams, G. I., Butts, C., Stephenson, L. W., Cooke, W., op. cit., p. 50.

[26]Adams G I., Butts, C., Stephenson, L. W., Cooke, W.—op. cit., p. 54.

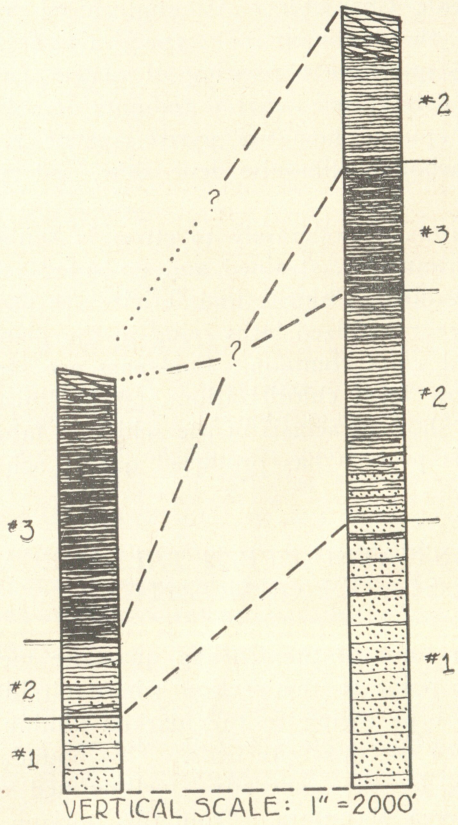

FIGURE 4

Figure 4. Columnar sections of the upper part of the Talladega series. Shorter column represents the area near Erin, Clay County; taller column is for the area near Bull Gap, Clay County. No. 1—Cheaha quatzite member; No. 2—Undifferentiated quartzites, phyllites, slates; No. 3—Erin slate member. Dashed and dotted lines are suggested correlations. The graphitic slates of the Bull Gap area may be equivalent to the Erin slate, but if so, there appears to be a lensing or faulting out of this rock type between the two areas. Each section is terminated at top by the Whitestone fault adjacent to which the rocks are rhomboidally sheared and silicified phyllites.

The quartzites are generally massive and well-bedded, with strata ranging from a few inches to ten or more feet in thickness. Bedding planes are marked by thin partings and beds of phyllite whose schistose structure is parallel to the bedding planes.

Petrographic Character: Although basal beds are locally conglomeratic, the dominant rock type is a light gray, medium to coarse-grained quartzite consisting of quartz (up to 95%) and containing as accessories variable amounts of chlorite, fine grained muscovite, epidote, hematite, pyrite, apatite, zircon, orthoclase, plagioclase, carbonate, limonite, leucoxene, and rutile.

Quartz forms a moderately to strongly schistose mosaic set with partly granulated, strained and embayed relicts of original detrital sand grains. Chlorite and sericite are present in the mosaic as small recrystallized laths lying in the plane of schistosity. Epidote granules are common. Feldspars are strained and fractured and show local chloritization and kaolinization. Most of the quartzites show cataclasis of the schistose fabric and, in some specimens, this process has produced quartz schists and mylonites.

UNDIFFERENTIATED UPPER TALLADEGA PHYLLITES, SLATES, QUARTZITES.

The upper limit of the Cheaha quartzite member has been placed at that point in the section where phyllite becomes the dominate rock type owing to the marked diminution in number and thickness of the quartzite beds. This boundary is expressed topographically by the generally well-defined eastern base of Talladega-Rebecca Mountain. From this horizon up to the Erin slate member the section consists principally of fine-grained chloritic and sericitic quartz schists or phyllites with interbedded, thin, and locally ferruginous quartzites. The same rock types are present west of Talladega-Rebecca Mountain and also occur above the Erin slates.

Petrographic Character: The phyllites are medium to dark greenish gray strongly schistose rocks. They usually contain at least 50% quartz plus a little feldspar and variable amounts of chlorite, fine grained muscovite and epidote. Minor accessories include tourmaline, apatite, zircon, rutile, leucoxene, hermatite, graphite, pyrite, limonite, and carbonate.

Like the quartzites, these rocks have been considerably sheared, but, where the quartzites have yielded to shearing stress by granulation, the phyllites have been minutely folded and sliced.

In most specimens there is a microscopic folding of the micaceous laminae with fracture cleavage developed at small intervals parallel to the axial planes of the folds. This deformation has been attended by some granulation of quartz and a pronounced recrystallization of the micas and quartz.

ERIN SLATE MEMBER.

The rocks of this member are best developed near Erin, Clay County, where they are very fine grained fissile graphitic quartz sericite slates and phyllites. A typical specimen contains quartz (70%), graphite matter (20%), sericite (8%), and minor amounts of pyrite and chlorite. All constituents are exceedingly fine grained except for small veinlets of quartz. Cleavage is defined by the parallel orientation of laths of sericite which are up to 0.03 millimeters in length and by a streaking of the graphitic matter. This latter feature may also record the original bedding. The slaty cleavage is locally finely corrugated and cross-cut by a well developed fracture cleavage parallel to the fold axes. (Figures 5A and 5B.)

Where the Erin rocks are somewhat coarser grained and more recrystallized they are classed as graphitic phyllites. These phyllites are usually strongly microfolded and faulted.

In the type locality, at Erin, Clay County, the Erin member is at least 2800 feet thick. Its true thickness cannot be measured since the upper limit is determined by the Whitestone fault. In other areas lithologically similar black slates and phyllites are overlain by nongraphitic phyllites. These rocks are mapped as Erin slates and phyllites although they may not be stratigraphic equivalents of the true Erin slate.

METAMORPHISM.

The quartzites, phyllites, and slates of the upper Talladega series are of low grade or epizone rank in the scale of regional metamorphism. These rocks have been derived, under conditions of strong shearing stress and low temperatures, from a series of conglomeratic and arkosic sandstones, ferruginous sandstones and shales, and carbonaceous shales.

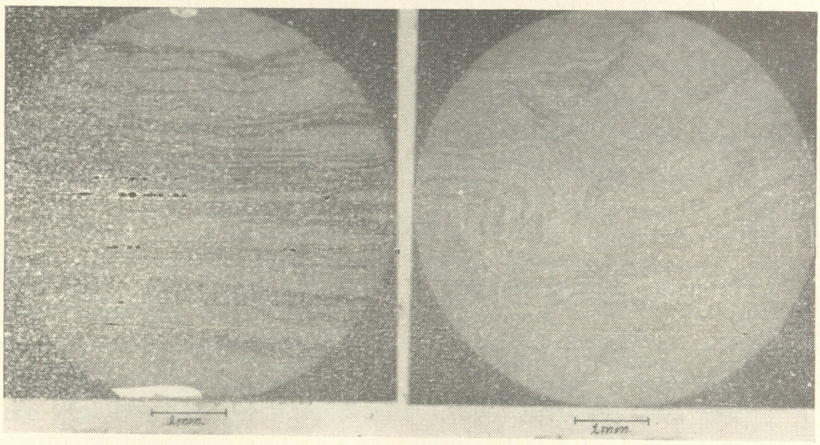

FIGURE 5A FIGURE 5B

Figure 5A. Erin slate. Sheared and microfolded graphitic quartz-sericite slate. Low grade metamorphic rank is attested by the incomplete and fine-grained recrystallization of quartz, sericite, and carbonaceous matter. Streaks of this latter material may define original bedding. (Locality: SE ¼, Section 21, T. 19S., R. 7E.)
Figure 5B. Erin member. Poorly graphitic quartz-sericite phyllite with strong microfolding and faulting along conjugate shear planes. Recrystallization is more advanced than that shown by the slate in Figure 5A. Quartz mosaic is especially well developed in apexes of folds. (Locality: SW ¼, Section 22, T. 19S, R. 77E.)

In the slates are recorded only the beginnings of mineralogical change. The micaceous minerals and quartz have at least partly recrystallized. However, the fine grained clastic texture of the original sediments is still evident and the finely divided carbonaceous matter has only locally been fixed as graphite. The cleavage of these slates is apparently parallel to bedding and is defined by the parallelism of the micas. It is a true schistosity and is not a fracture cleavage.

The phyllites are of slightly higher metamorphic grade. These oxides as hematite. Chlorites commonly are set with cleavages and muscovite; carbonaceous matter is fixed as graphite and iron ovides as hematite. Chlorites commonly are set with cleavages transverse to the schistosity and locally are porphyroblastic.

In the quartzites the imprint of metamorphism is recorded in the extensive recrystallization of quartz in a schistose mosaic and in the development of laths of chlorite and sericite, grains of epidote and hematite.

A striking feature of the conglomeratic quartzites is the presence of slightly flattened spindle-shaped quartz pebbles up to three inches in length. These have a regional orientation and are believed to have been produced by an elongation of original rounded quartz pebbles during metamorphism.

The highest grade of metamorphism in the rocks of the Talladega series is found in a narrow zone bordering the Whitestone fault and the Hillabee sill. These border zone rocks, belonging to several stratigraphic horizons, are quartz-sericite schists, graphitic quartz-sericite schists, and epidote-quartz-chlorite schists. They have been extensively sheared along closely spaced rhomboidal planes and strongly silicified. Quartz, commonly accompanied by pyrite, occurs as veins or, more characteristically, as flat pods or lenses occupying opened spaces along the shear planes. Rocks of this type occur along most of the eastern margin of the Talladega series. The facies is especially well developed in the area from Chambers Spring to Pyriton.

STRUCTURE.

Over much of the area occupied by the Talladega series bedding and cleavage or schistosity are parallel. In the thicker portions of the phyllite section, however, a considerable divergence of these structural elements may go unrecognized because of the obscurity of bedding. That such divergence does exist is shown in the area north of Hollins. A low ridge southeast of and parallel to Rebecca Mountain is developed on several thin quartzite beds. The regional schistosity transects this ridge at low angles in a northerly direction and dips southeastward at slightly greater angles than do the quartzites.

Regional structure is best shown by the pattern of the Cheaha quartzite. The long zig-zag trace of these beds indicates clearly the presence of broad, shallow, eastward plunging flexures which deform a southeastward dipping monocline. A broad synclinal structure lies opposite and plunges under the northernmost lobe

of Ashland shists and the expanded area of the Hillabee sill. An anticlinal axis is marked by the bend in Rebecca Mountain near Bull Gap.

Wherever observed, the lower limit of the Cheaha quartzite shows a moderate to marked structural discordance with the underlying rocks. At Clairmont Gap and Adam Gap, there is, in addition, a mass shearing and local mylonitization of the lower quartzite beds. In contrast, at Chandler Springs basal structural discordance is lacking but there has been thrusting within the quartzite section. (Figure 6.)

Extensive granulation of basal quartzite beds and structural discordance with underlying rocks indicate the existance of a sub-Cheaha thrust of interstratal nature along which movement has been locally extensive. In other areas, as shown in Figure 6, thrusting may have been within the quartzite section rather than at its base.

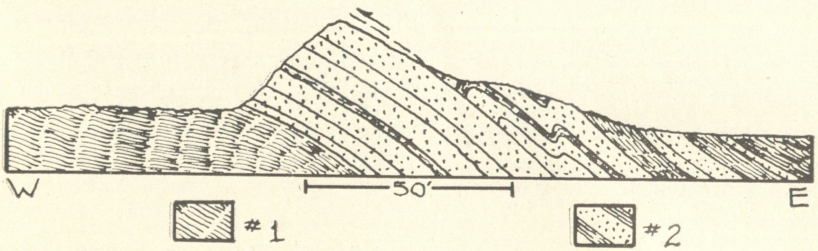

FIGURE 6.

Figure 6. Section through the Cheaha quartzites and associated slates—phyllites at cut along Atlanta, Birmingham, and Coast R. R., Chandler Springs. Basal quartzite beds are structurally conformable with underlying graphitic slates. Thrusting within the quartzite section is indicated by drag folding of overlying quartzites and phyllites and by the absence of some 350 feet of quartzites which should normally be present above the base of the Cheaha member. (Locality: SW ¼, Section 35, T. 19S., R. 6E.)

Detailed structures of the Cheaha quartzite beds are somewhat more complicated than is indicated by the regional outcrop pattern. Gentle flexures, plunging in the direction of dip, are of common occurrence. Marginal faulting subsidiary to the sub-Cheaha thrust is present locally and there has been a marked rotation of some blocks defined by these faults. The best developed

of these marginal faults are a system whose traces lie in the direction of quartzite dip and whose planes are inclined at very gentle angles northward. On the northern and western slopes of Talladega-Rebecca Mountain these faults appear to merge with the sub-Cheaha thrust. They are responsible for local offsets and thickenings of the quartzite section but commonly are of small displacement.

Near section 32, T. 18S., R. 8E., the southward trending Talladega Mountain makes an almost right angle bend to the west. From the apex of this bend a series of quartzite ridges extend south almost to Pyriton. At their southern extremity these ridges are maintained by an anticlinal fold. The western limb of the anticline is quite steep and passes northward into a thrust fault which merges with the sub-Cheaha thrust. In the tangle of ridges formed by the junction of the southward trending ridges with Talladega Mountain this fault is paralleled by several similar faults. Along each of these movement has been westward and has resulted in a pronounced imbrication and thickening of the Cheaha section. In the small fault blocks some of the basal quartzite beds have been closely crumpled forming narrow, broken, southward plunging folds.

The small group of ridges lying in section 2, T. 20S., R. 6E., has been formed on a wedge or splinter of quartzites thrust westward up through and over the phyllites. Basal members of the quartzite series have been strongly sheared along planes that transect bedding. Bedding strikes almost north-south and dips eastward whereas the shear planes strike northeast and dip southeast.

Structures developed in the slates and phyllites overlying the Cheaha member conform generally to its regional pattern. These structures, however, are finer grained and more complex. This reflects the manner of yielding to deforming stresses inherent in the two rock types. The massive quartzite beds have been flexed, faulted, brecciated, and sheared, whereas the less competent slates and phyllites have been rather intricately folded, corrugated, and crumpled and, over wide areas, have developed a striking wrinkling of cleavages and related miscoscopic slicing, forming a false cleavage.

The lower limit of the slate-phyllite section is generally conformable to the Cheaha beds but in some areas there has been a more or less interstratal thrusting and dragging of these beds over the quartzites resulting in structural discordances. The upper limit of the Talladega rocks is determined by the Whitestone fault which, transecting the structure of the slate-phyllites, rises from a horizon immediately above the Cheaha quartzite at Pyriton to a point that may be well above the Erin slate about one mile west of Millerville.

Structure of the slate-phyllite belt is most complex in the area lying east of Bull Gap and coinciding with the anticlinal complex developed in the Ashland Mica Schist. On the northern flank of this area the slate-phyllite belt is structually conformable with the Whitestone fault and forms a tightly compressed anticlinal wedge plunging eastward toward Millerville. The crest of this fold is cut by northeasterly striking thrusts which can be traced southwestward for several miles. South of this faulted anticline is a more complexly folded and faulted lobe of slates and phyllites which extends southeastward to a point about one an one half miles northwest of Elias. These two lobes are separated by a westward projection of the Ashland schists.

In the area lying south of Talladega Mountain between Pyriton and Clairmont Springs, the Southward-trending thrusts that have affected the Cheaha quartzites may be traced into the slates and phyllites, where bedding is offset, and in a few instances to the Whitestone fault. There is no evidence that any of these faults involve the Hillabee sill, however. In addition to these faults, the silicified slates and phyllites bordering the Whitestone fault are generally thrust for short distances over the rocks lying north and west of them.

The structure of the upper part of the Talladega series near Erin is of critical importance in determining the age of the series. The graphitic slates at this locality have long been known to carry fossils of Carboniferous age, but in recent years workers in southern Appalachian stratigraphy have hesitated to include these slates in the Talladega series. They have chosen to regard the slates near Erin as a fenster-exposure produced by erosion through the Talladega thrust-block. This interpretation, advanced by

Jonas[27], was accepted by the U. S. Geological Survey on the Geological Map of the United States (1932) and was followed by Park when mapping the upper part of the Talladega series near Erin.[28] In 1936, Crickmay reported that "the Erin shale is entirely surrounded by Talladega phyllite, but, as Jonas first stated and Park later demonstrated, it does not occupy a lens within the series, but is exposed in a window through a thrust fault."[29]

The writer disagrees with these previous workers both as to nomenclature and structural interpretation as indicated by the following comments.

1. The fossiliferous beds at Erin are not "shale," but slate of low grade metamorphic rank. The slate is locally folded, wrinkled, sheared and injected by pyrite-bearing quartz veins and pods, and by turquoise veinlets.

2. Southeast of Erin the typical black slates become increasingly contorted and silicified as the belt of slightly higher grade graphitic quartz-sericite phyllites lying adjacent to the Whitestone fault and the Hillabee sill is approached. There is a gradation from smooth slates through wrinkled slates with small quartz pods and veinlets to black slates with large quartz veins, stringers, and pods. (Figure 7) Rocks of the border zone show a well-developed rhomboidal shear pattern and intense silicification.

3. Structural discordance between the typical Erin slates and the silicified phyllites to the southeast are present only locally. (Figures 8 and 9.) In other areas near Erin such discordance is not present. These relations suggest that, although the phyllites are locally thrust northwestward over the slates, there has not everywhere been fault movement between these two rock types. Furthermore, the faulting, where developed, has been of small extent and the fault (Figure 9) is not the Cartersville thrust over which the entire Talladega block has moved northwestward.

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[27]Jonas A. I.—Structure of the Metamorphic Belt of the Southern Applachians, Am. Jour. Sci., Vol. 24 1932 pp. 231, 243.

[28]Park, C. F., Jr.—Notes on the Structure of the Erin Shale of Alabama, Jour. Wash. Acad. Sci., Vol. 25, 1935, pp. 276-279.

[29]Crickmay G. W.—Status of the Talladega Series in Southern Applachian Stratigraphy Bull. G. S. A., Vol. 47, 1936, p. 1380.

FIGURE 7

Figure 7. Erin slates exposed in railroad cut at Watts Mill. Cleavage of the slates strikes N65E and dips S25E, 70 degrees. To the left of the hammer are several of the large quartz pods, stringers, and veins that become characteristic of the slates as the Whitestone fault is approached. Cleavages of the slate here are locally finely wrinkled and sliced by microfaulting. (Locality: NE ¼, Section 23, T. 19S., R. 7E.)

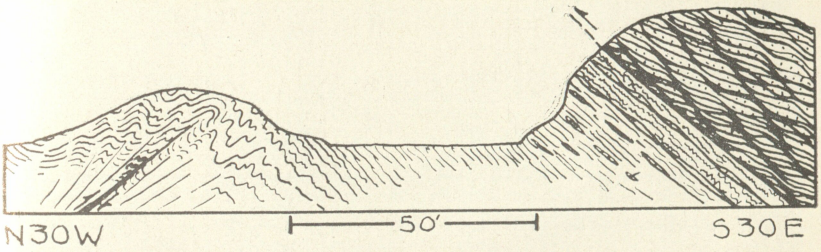

FIGURE 8

Figure 8. Structures of Erin slate and phyllite near the Whitestone fault. The slates in the northwest part of this section are involved in a small northwestward dipping thrust which passes upward into an anticline. Further toward the southeast the slates are less deformed but contain many quartz veins and pods. These silicified slates are overlain by rhomboidally sheared and strongly silicified phyllites and are separated from the latter by a thrust or small displacement. Northeast of this point the slates appear to grade upward, without fault break, into the overlying phyllites. (Locality: NW ¼, Section 28, T. 19S., R. 7E.)

4. The discordance in strike between schistosity of the Erin slate and the "Talladega formation" cited by Park[30] as evidence of a fenster is much less than that occurring in arears of similar size within the Erin slate. (Figure 10.)

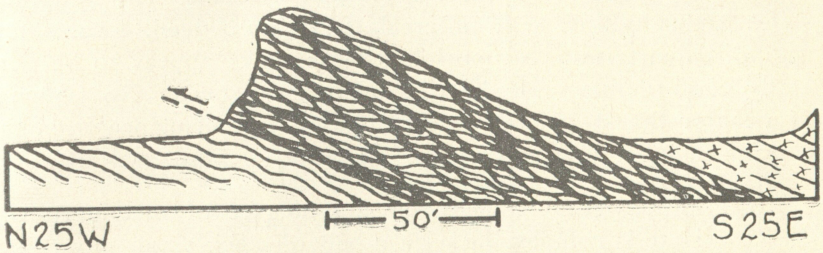

FIGURE 9

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Figure 9. Fault contact between Erin slates (below) and rhombodially sheared and silicified sericite phyllites (above). Small extent of thrusting is suggested by gentleness of drag folds below the fault. These probably would be tighter and have axial planes dipping steeply toward the southeast if fault movement had been great. Phyllites are overlain to the southeast by the Hillabee sill. (Locality: NW ¼, Section 28, T. 19S. R. 7E.)

[30]Park, C. F., Jr.—op. cit., p. 278.

FIGURE 10

Figure 10. Exposure of Erin phyllite at Clairmont Springs. These rocks have been strongly crumpled so that changes in structural attitude within very short distance are common. (Locality: NE ¼, Section 29, T. 19S., R. 7E.)

5. Northwest of Erin, the slates grade into less graphitic slates and phyllites with intercalated thin-bedded, locally ferruginous quartzites. Structurally, these rocks appear to be generally conformable with the Cheaha quarzite beds. No evidence of a major thrust separating the slate-phyllite sequence from the Cheaha member was noted.

6. In petrographic character and degree of metamorphism the Erin slate is comparable with a belt of black slates more than ten miles long extending from Hollins northeastward beyond Marvin Chapel. Bedding, cleavage, and faulting of this southern belt indicate its conformable relationship to adjacent beds of the Talladega series.

The writer's field observations and structural and stratigraphic interpretations are summarized in Figure 11A. It is concluded that the Erin slate is an integral part of the Talladega series and that the fossils it contains determine the age of this portion of the series.

FIGURE 11A

Figure 11A. Aerial photograph showing the type locality of the Erin slate, Erin, Clay County, Alabama. Scale: 1-20,000. Photograph by production and Marketing Administration, U. S. Department of Agriculture.

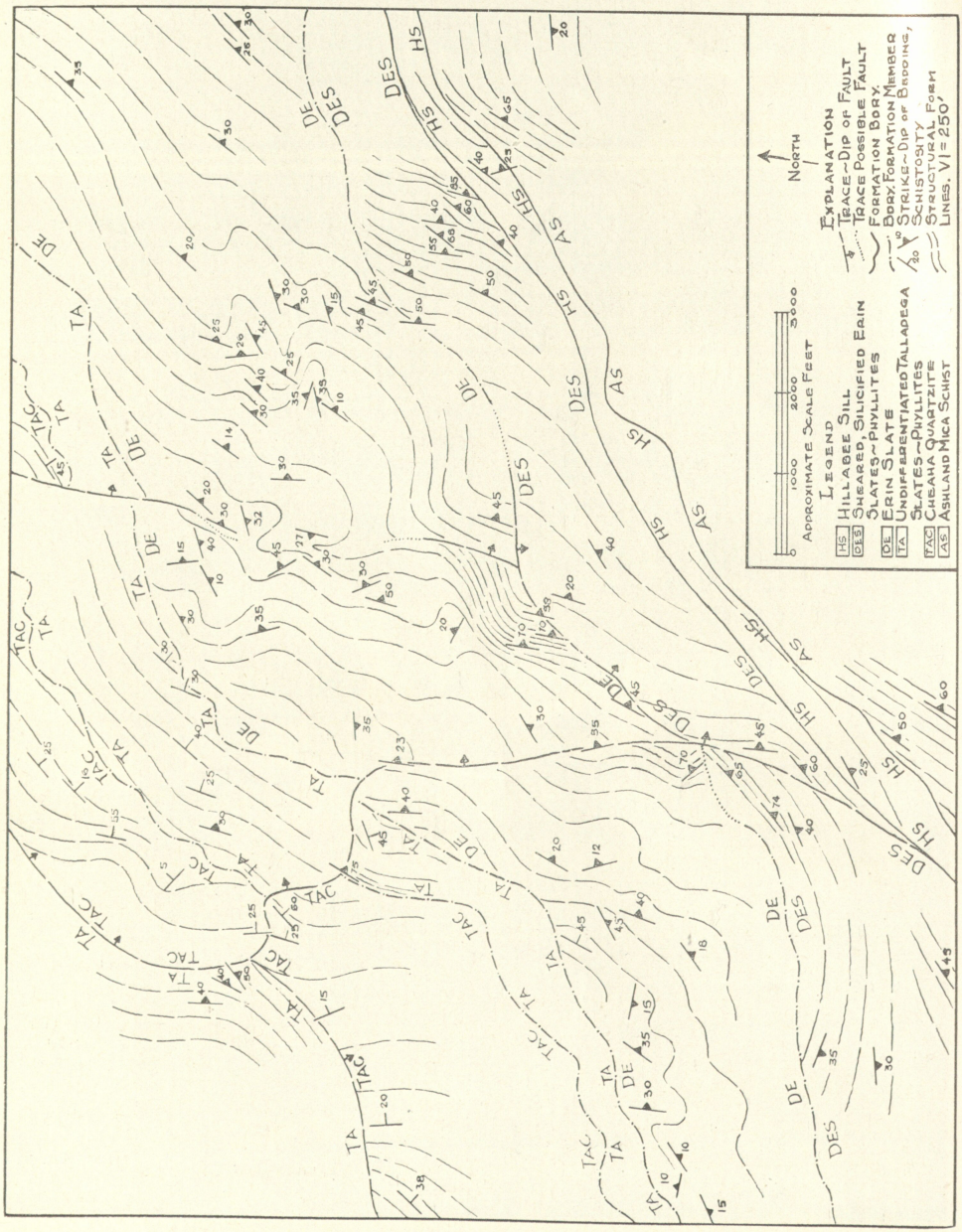

FIGURE 11B

Figure 11B. Geologic map of the area covered by Figure 11A. Map symbols are the same as those used in the regional geological map (insert).

AGE OF THE TALLADEGA SERIES.

As late as 1926 the upper portion of the Talladega series was regarded as embracing a period of geologic time from the Devonian through the Pennsylvanian. Devonian fossils had been found in the Jemison chert and Yellowleaf quartz schist in Chilton County[31] and Pennsylvanian plant fossils were known to occur in the Erin slate of Clay County.[32] (Figure 12.) These three formations were mapped and described as members of the Talladega series.

The question of the age of the series was reopened in 1932 when, on the geological map of the United States, the U. S. Geological Survey excluded the fossiliferous horizons from the Talladega series and indicated their outcrops as fenster exposures. The Talladega series of Alabama was mapped thereon as the Wissahickon schist and assigned to the pre-Cambrian. Jonas[33] in 1932, mapped the Talladega series (plus the Hillabee sill, Ashland Mica Schist, and Wedowee formation) as "crystalline schist of low-rank metamorphism indicative of regression (albite-chlorite schist and garnetiferous phyllonite, hornblende gneiss and mylonitized granite gneiss, indicative of intense differential deformation, augen gneiss and granite mylonite.)" In 1936 Crickmay[34] reviewed all available evidence concerning the age of the Talladega series and concluded that this evidence favors a pre-Cambrian age.

Detailed structural study of the Talladega rocks near Erin, Clay County indicates that the Erin slate is a portion of the upper Talladega series which, thus, includes strata of Pennsylvanian age.

Additional paleontological evidence of age was found in 1941 in quartzites of the Cheaha member. A small portion of silicified segmented stem, resembling those of the crinoids or blastoids, was discovered in a boulder of quartzite a short distance be-

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[31]Adams, G. I., Butts, C., Stephenson, L. W., Cooke, W.—op. cit., pp. 57-58.

[32]Smith, E A.—Carboniferous Fossils in "Ocoee" Slates in Alabama, Science, New Series, Vol. XVIII, No. 541, 1903, pp. 244-246.

[33]Jones, A. I.,—op. cit., p. 231.

[34]Crickmay, G. W.—op. cit.

Figure 12. Pennsylvania plant fossils from the Erin slate member of the Talladega series, Erin, Clay County.

Lepidostrobus hobbsii, n. sp., D. W., XI. No. 1—Fragment of fruiting cone from which the bracts have been broken away, showing the partly eroded spore scars arranged in oblique rows similar to the leaves upon the stem; No. 2—apparently part of a crushed and elongated cone; No. 3—polish cross-section of cone showing edges of the sporangiophores and their connection with the central axis of the cone. (After Geological Survey of Alabama, Special Report No. 14, 1926, Plate 70.)

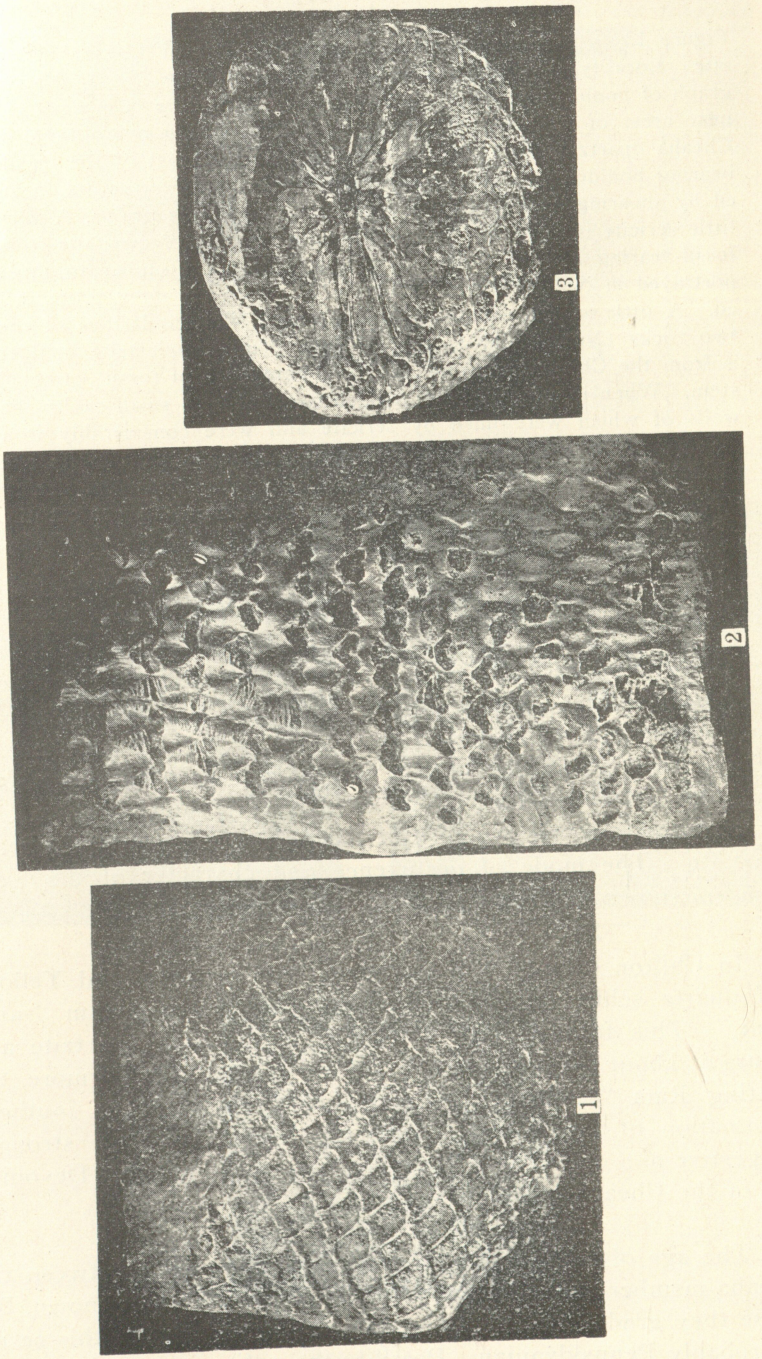

FIGURE 12

Figure 13. Probable crinoid stem from boulder of Cheaha quartzite. Locality: SW ¼, Section 16, T. 19S., R. 7E. No. 1—Photograph of boulder in which fossil occurred. Exposure is in road cut near crest of Talladega Mountain. No. 2—Photomicrograph of Cheaha quartzite from ledge about 100 feet northeast of the fossil-bearing boulder. Shows strongly developed mortar structure formed by shearing and peripheral granulation of quartz grains. A very little sericite is present. No. 3—Photomicrograph of quartzite from fossil-bearing boulder. Texture and structure are similar to those portrayed in No. 2 although effects of shearing are more pronounced. A little sericite occurs in the mortar. The similarities of the two rocks (Nos. 2 and 3) are evidence that the quartzite boulder is from the Cheaha member. No. 4—Photograph of fossil "crinoid" stem. When in situ, the stem was surrounded by a small cavity the walls of which were lined by sericite and were considerably iron stained. It is probable that the stem was transported to its site of deposition in a small mud pellet. This latter material, during metamorphism, was altered to sericite and served to protect the silicified stem from crushing.

low the summit of Talladega Mountain about 0.5 mile northeast of Clairmont Gap. Petrographic examination shows that the quartzites of the boulder and of the nearest ledge are similar. Only surface structures of the fossil have been preserved and these do not permit special or even generic identification. Its presence, however, is evidence of the Palozoic age of the Cheaha quartzite. The mode of occurrence and character of the fossil stem are shown in Figure 13.

In Chilton County, the Devonian Jemison chert and Yellowleaf quartz schist immediately overlie the Butting Ram "sandstone." This formation is similar to the Cheaha quartzite and occurs at about the same stratigraphic horizon. Furthermore, the Butting Ram "sandstone" strikes directly toward the southern termination of the Cheaha quartzite. These facts are strongly suggestive of a correlation of the two and of the possible Devonian age of the Cheaha quartzite.

The age of the phyllite--quartzite-slate sequence between the Cheaha member and the Pennsylvanian Erin slate is not known. Because they grade into the Erin slate, the upper part of this series is probably Pennsylvanian. Possibly the entire sequence is Penn-

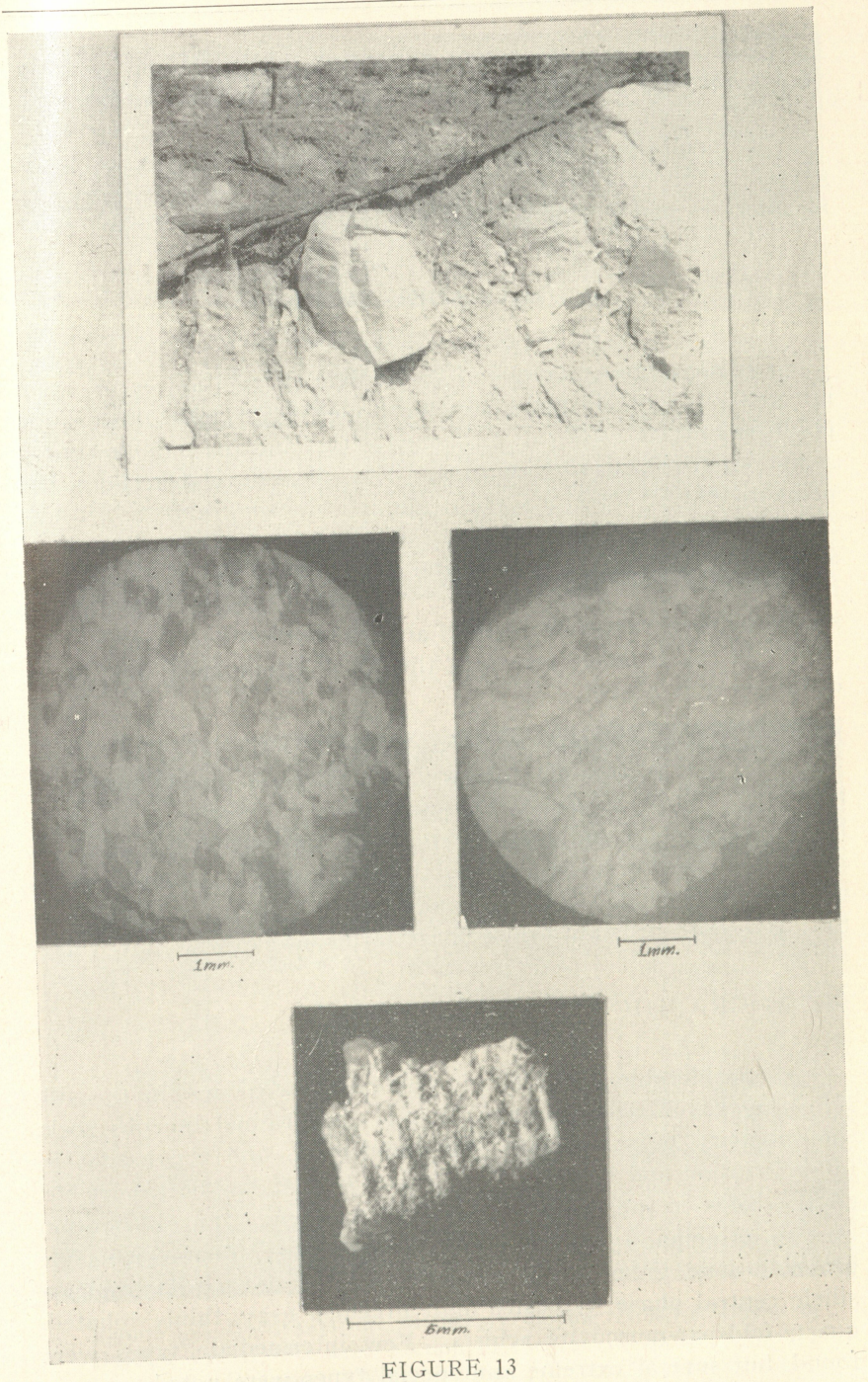

FIGURE 13

sylvanian but it may represent discontinuous deposition from Devonian through Mississippian or even into Pennsylvanian time.

In conclusion, the upper part of the Talladega series is regarded as upper Paleozoic in age and is believed to contain representatives of Devonian, Mississippian and Pennsylvanian strata.

HILLABEE SILL

The meta-igneous rocks of the Hillabee formation occur as an injected body of sill-like character lying between the low grade phyllites and slates of the Talladega series and the medium grade schists of the Ashland formation. The sill is developed along the plane of the Whitestone fault, though, locally, narrow sill-like apophyses of the Hillabee are present within the bordering metasediments, and masses of the latter are to be found included within the main body of the Hillabee. The outcrop pattern of the sill shows marked variation in trend and in width. Over much of its course in the Hillabee map area the sill is attenuated; for short distances it is absent.

Over the greater part of its area of outcrop the Hillabee sill is deeply weathered and is expressed topographically as a valley belt. (Figures 14 and 15.) Parts of the sill have been more resistant to erosion: near Pyriton the mineralized schists form a narrow, sharp ridge; in the expanded outcrop area near Chambers Spring a more resistant schist phase forms a very wide, low ridge.

PETROGRAPHIC CHARACTER.

A considerable diversity of rock types occur within the sill, reflecting variations in composition of the original igneous rock, the intensity of subsequent metamorphism, and the extent of mineralization and hydrothermal alteration. It has been possible, on the basis of megascopic appearances, to map the distribution of two principal types: a mafic border phase, dominantly fine grained, dark green chlorite-epidote-hornblende schists, and a silicic central phase, typically light greenish gray, thinly foliated, quartz-feldspar-muscovite schists. Few intermediate types were found, but several extreme and special types were noted.

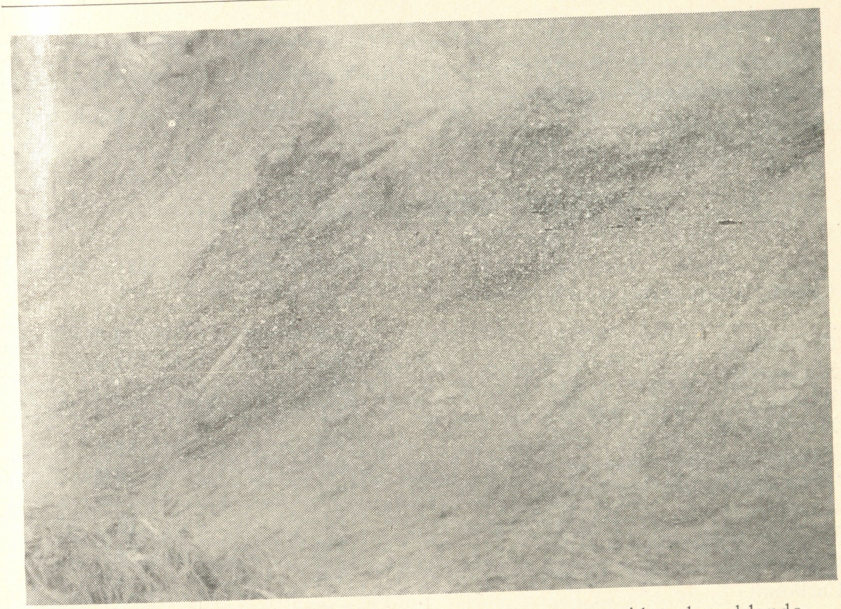

Figure 14. Deeply weathered Hillabee albite-epidote-hornblende schist. Strike is N60W, dip is N3OE, 45 degrees. (Locality: S Central ½, Section 16 T. 21S., R. 7E.)

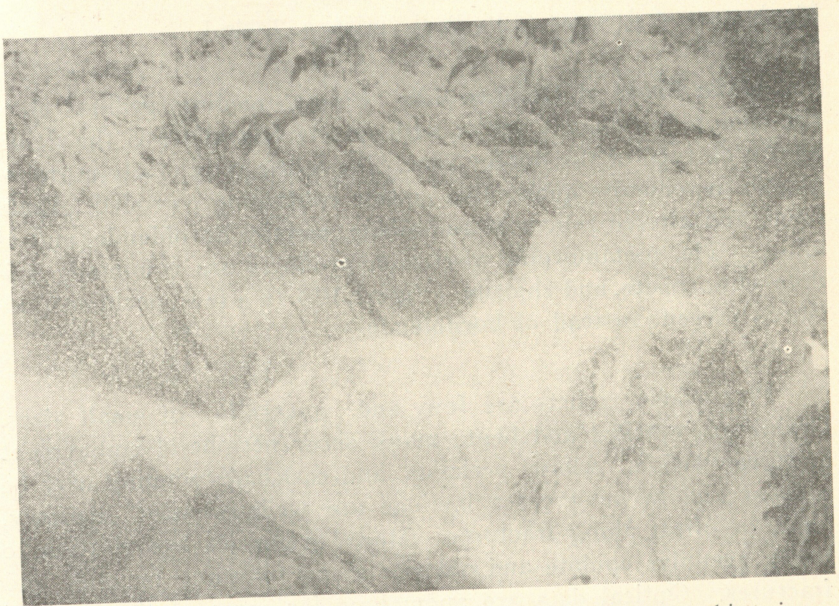

Figure 15. Good exposure of steeply dipping Hillabee schists in Hatchet Creek. For cross-section of the rocks exposed here, see Figure 20. (Locality: SW ¼, Section 3, T. 21S., R. 6E.)

Modal analyses of the schists are shown in Table I. Significant differences in composition, however, are somewhat more clearly indicated by the averages of several analyses of each type, as shown below.

AVERAGE MODE (Percent by Areas)

	Silicic Phase*	Mafic Phase**
Quartz	31.5	4.4
Albite	37.4	31.7
Orthoclase	2.1	1.4
Muscovite	13.9	1.0
Biotite	3.1	—
Hornblende	1.0	21.5
Pargasite	1.3	4.0
"Actinalite"	0.9	—
Chlorite	1.1	12.8
Epidote	3.6	10.8
Clinozoisite	3.4	9.7
Carbonate	—	1.4
Accessories	0.7	0.9
"Saussurite"	—	0.4

* Average of Analyses 1-10 inclusive, Table I.
** Average of Analyses 14-16, 18-21, inclusive, Table I.

Mafic Phase of Hillabee Sill: Fine to medium grained chlorite-epidote-hornblende schist with quartz and albite is the dominant rock type of the border zone. The fabric is typically a granoblastic to schistose quartz-like mosaic containing corroded, granulated, and altered relicts of amphibole, usually hornblende, and of albite. The metamorphic alteration products are commonly epidote, clinozoisite, and chlorite. (Figure 16.) In a few specimens biotite is present instead of hornblende.

Plagioclase relicts are few, and generally of small sizes. Grains are cracked and bent; many show peripheral embayment and granulation. Albite, pericline, and carlsbad twinning may be present and in most cases laminae are wedge-shaped, shadowy, bent, or offset along fractures. Many grains show alteration to finely granular epidote and chlorite along twinning lamellae and fractures. Optical data are anomalous for some of the strained and crushed grains. Data for the less altered relicts indicate a plagioclase of nearly pure albite composition—Ab 95-100.

TABLE I

Approximate Modal Analyses (% by areas)—Hillabee Schists

Mineral	Specimen No.																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Quartz	45	45	40	30	45	40	20	10	40	tr	15	7	15	5		11)	35	(5	5	5	(**)		23
Albite	40	35	46	29	10	15	45	64	15	75	45	45	25	44	41	) 30)	(*)	((30	30	27	20	4	20
Orthoclase		9		2		?	10					10			5					5			
Muscovite	10	1	3	25	30	30	10	10	20						2		5					4	tr
Biotite		2	4					tr	5	20							27						
Hornblende				10								35			40	16		30	20		45	90	
Pargasite					5	8					15		25	10						18			
"Actinolite"				tr		1—		8								tr							
Chlorite		3					3		5		3	1	5	20		18	1	15	15	20	2		35
Epidote	4	2	4	tr	3	4	3	2	14	tr	10	2	10	13	tr	16	30	9	18	17	3		
Clinozoisite	1	3	3	4	7	2	6	5	tr	3	5		20	1	10	7		5	10	5	30	tr	
"Saussurite"											6									3			
Carbonate														5				5					
Accessories:														tr									
Pyrite			tr			1—			tr	1	1	tr				1	2	tr	1—	tr	tr		20
Ilmenite		tr																					
Leucoxene		tr						1		tr					2								
Apatite				tr	tr							tr					tr						tr
Sphene		tr		tr	tr		tr	tr	tr	1—	tr	tr	tr	2	tr	1	tr	1	1	tr	tr	2	2
Limonite						1—			1									tr					
	629-41	Cl-9-1	Cl-65	3256-41	Cl-79A	Cl-79	325d-41	Cl-108	200-41	240-4	329-41	Cl-33	199-41	1996-41	243-41	Cl-9-4	Cl-852	Cl-15	Cl-89	231-41	Cl-86	Cl-114	Cl-9A
(Thin-section No., Geol. Surv. Ala.)	Silicic Phase					Intermediate Types									Mafic Phase							Special Types	

* Dominantly introduced quartz
** Dominantly albite

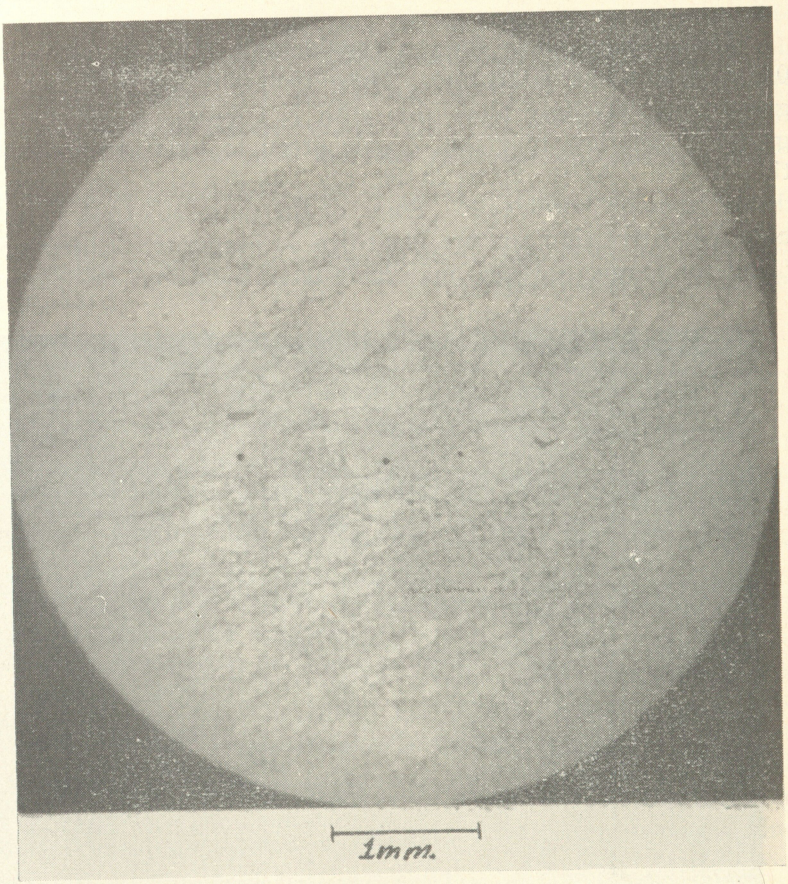

FIGURE 16

Figure 16. Photomicrograph of typical mafic phase of Hillabee sill. Albite-epidote-chlorite-pargasite schist with sphene, carbonate, and pyrite. Subporphyroblastic quartz-albite-carbonate schistose mosaic set with chlorite, epidote and sphene. Small relict needles of pargasite occur within chlorite. Rock is almost entirely reconstituted from an original igneous rock of "albite-quartz-diorite" character. (Locality: NE ¼, Section 19, T. 19S., R. 7E.)

The most common mode of plagioclase (albite) is as a subequigranular granoblastic mosaic with quartz. In some specimens the beginnings of a subporhyroblastic habit may be noted. These grains are clear, unstrained and commonly include granules of epidote, small needles and blades of amphibole. The latter usually show a preferred orientation in the direction of schistosity.

Hornblende relicts show a considerable range in size—from 0.5 x 0.3 to 0.18 x 0.008 mm. These generally are of rather pale green color, strongly pleochroic with X colorless to pale yellow green, Y colorless to green, Z pale green to blue green. Extinction angles. $Z \wedge C = 20$ to 25 degrees, and negative optic sign indicate common hornblende. Some of the more colorless varieties have a positive sign and are identified as pargasite. Either hornblende or pargasite relicts may have large inclusions of apatite.

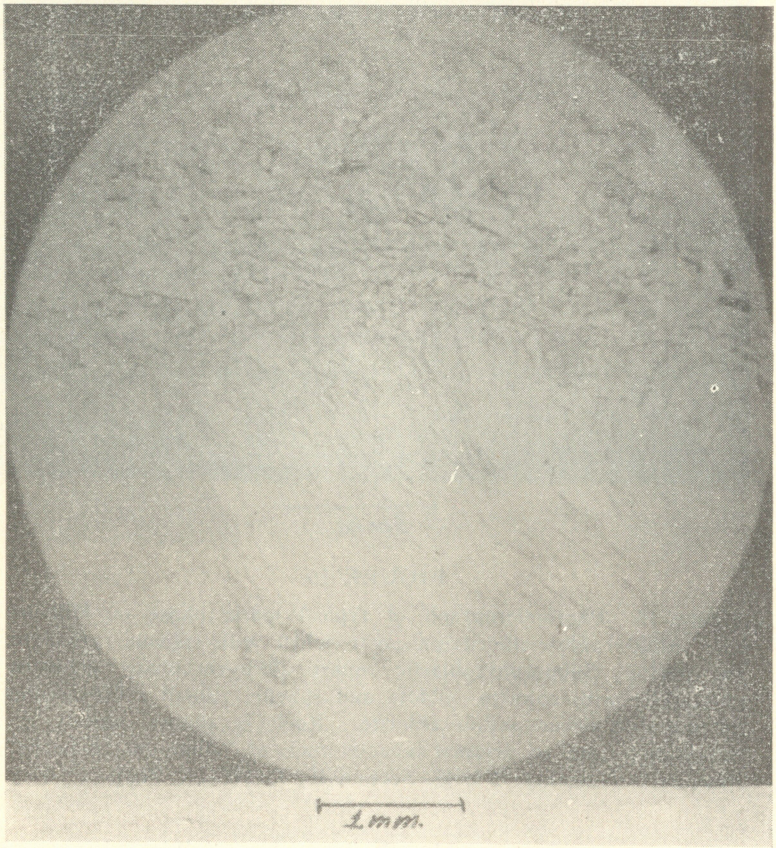

FIGURE 17

Figure 17. Photomicrograph of mafic phase of Hillabee sill. Albite-hornblende schist with a little quartz, orthoclase, epidote, and chlorite. A fluxion pattern is developed in introduced quartz by detachment and flowage of acicular cleavage fragments detached from original cataclastic hornblende grains. (Locality: NE ¼, Section 1, T. 20S., R. 6E.)

The larger relict grains show strongly the effects of pronounced differential movement. Grains are bent, broken, intersertal, rotated and strewn. A most striking feature of these grains is the common frayed or tattered shape caused by a separation of cleavages near grain ends, and, in many cases, by an apparent "floating" away of narrow cleavage laths. (Figure 17.)

Smaller relicts show less pronounced cataclasis but otherwise are similar to the larger grains. It is probable that these are merely smaller remnants of larger relict amphiboles.

Both sizes of hornblendes show, in a few specimens, a pronounced peripheral bleaching which may possibly be ascribed to an abstraction of iron and magnesium. This is believed to produce an aluminous amphibole of actinolitic appearance. Where this alteration has occurred the small needle and lath shaped amphiboles that are present as trains and swarms defining the schistosity are of the aluminous type.

Amphibole grains of all sizes commonly show a pronounced alteration to epidote minerals and to chlorite. Epidote is generally somewhat more abundant than the less ferrous clinozoisite but both are well developed and characteristic of the border zone rocks. The mode of epidote ranges from finely granular xenoblastic aggregates to large idioblastic and subidioblastics grains. Individual grains may show a variation in composition from clinozoisite to epidote but no definite zoning was noted. Furthermore, there is little to suggest a sequence in formation of clinozoisite and epidote. Some large grains of poorly developed radiate structure show alternate wedges of each mineral.

Epidote and clinozoisite are found at rims, along cleavages, and even as grains wholly enclosed within amphibole. They commonly produce a slight bleaching of the bordering amphibole.

A slight amount of diffusion during the course of metamorphism may be recorded by the epidote minerals which occur in areas a little removed from amphibole. On the other hand, such occurrences may record the complete replacement of amphibole with little or no diffusion. Some large patches of coarsely granular epidotes with interstitial quartz and albite suggest a fracturing and separation of the epidote minerals after their formation.

Chlorite, like epidote and clinozoisite, is most commonly present as an alteration along cleavages, fractures and borders of amphibole and biotite but, unlike the other minerals, its occurrence is somewhat sporadic. Where present, chlorite replaces the amphibole and frequently is in optical continuity with it.

Biotite is of very restricted distribution. Where it is present it occurs as small (0.01 x 0.002 mm.) laths of felted or schistose structure.

Minor amounts of highly altered orthoclase, muscovite, and accessories usually are present. Carbonate occurs in a few specimens as large idioblastic grains in the albite-quartz mosaic; ilmenite shows thick, well developed rims of leucoxene; pyrite is mostly a late introduction and is discussed in a following section; sphene is a common accessory, usually as spindle shaped granules, but in some specimens as blocky subidioblastic grains.

Silicic Phase of Hillabee Sill: The quartz-albite muscovite schists that make up what is described as the silicic phase of the Hillabee differ from the border rocks in several important respects. Quartz, feldspars, and muscovite are dominant biotite and hornblende are characterizing accessories; and minerals of the epidote and chlorite groups occur sparingly. Texturally, these schists present a more hiatal fabric with cataclastic relicts, usually of amphibole, albite, and quartz, set in a finely schistose quartz-albite mortar or a coarser grained schistose mosaic. (Figure 18.)

In some rocks, a decided banding is produced by alternation of muscovite-clinozoisite-epidote layers with quartz-albite mosaic; in others, the muscovite rich layers have an anastamosing rhomboidal pattern outlining granoblastic and cataclastic flaser.

Plagioclase is similar to that present in the chlorite-epidote schists. Relicts are considerably more abundant in the silicic rocks, however. These large grains are strongly cataclastic, altered, embayed, and replaced. Albite of the mosaic is the same as in the previously described rocks but generally is somewhat finer grained.

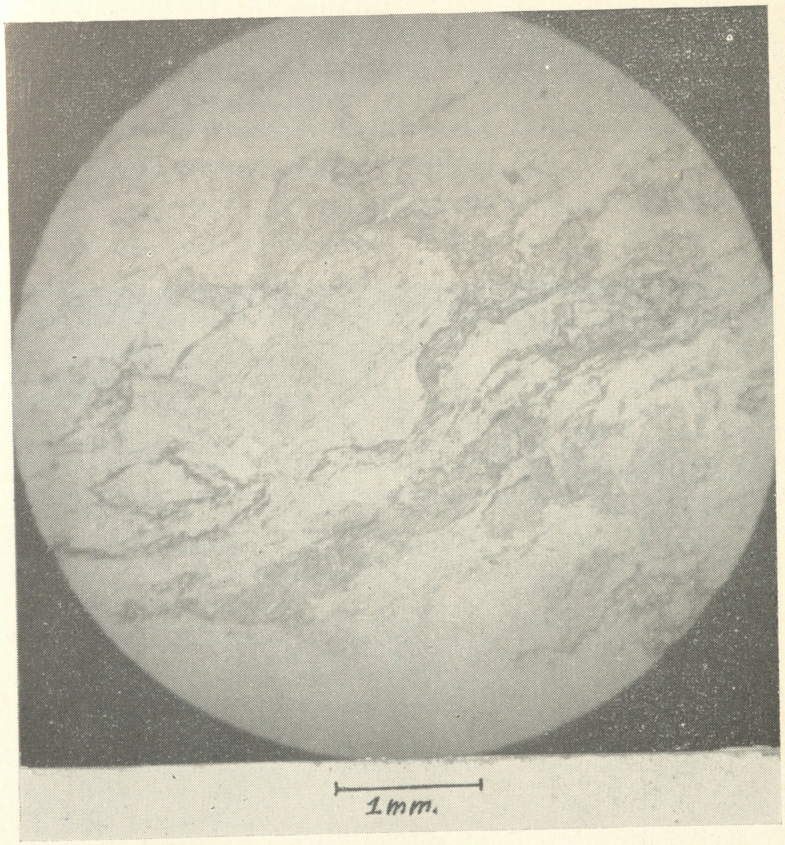

FIGURE 18

Figure 18. Photomicrograph of silicic phase of Hillabee sill. Quartz-albite-muscovite-pargastic schist produced by low grade regional metamorphism of an "albite granodiorite" instrusive. A relict phenocryst of paragasite shows strong catasclasis and a peripheral alteration to fine grained epidote nd clinozoisite. The schistose fabric is cataclastic and partly recrystallized quartz-albite and contains fine grained muscovite and a few acicular pargasite cleavage fragments. (Locality: NE ¼, Section 29, T. 20S, R. 6E.)

Certain large feldspar relicts are untwinned and show a strong alteration to sericite. These are tentatively identified as orthoclase although optical data are generally lacking. A few show negative sign and all indices of refraction are less than those of canada balsam or quartz.

Amphiboles, including hornblende, pargasite, and aluminous amphibole, are present as highly altered and replaced cataclastic relicts and as small laths and needles. The place of amphibole may be taken by biotite. Locally, the latter occurs as radial aggregates of brown laths interstitial to mortared albite in a manner suggestive of a little modified diabasic texture. (Figure 19.)

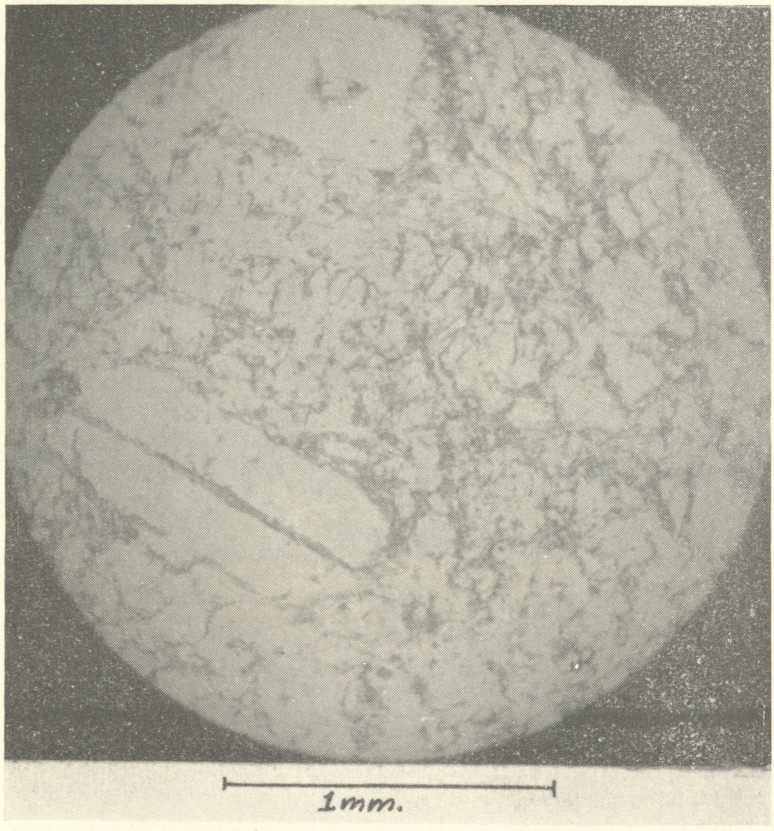

FIGURE 19

Figure 19. Photomicrogrph of silicic phase of Hillabee sill. Cataclastic and peripherally replaced albite phenocrysts in ground mass containing elongate albite grains with interstitial felted brown biotite suggestive of a slightly modified diabasic texture. (Locality: NE ¼, Section 21, T. 20S., R. 6E.)

The modes of chlorite, epidote, and clinozoisite are like those in the border rocks but these minerals, although of idioblastic to subidioblastic shapes, are commonly smaller and much less abundant. Some larger grains of epidote have thrust aside enclosing muscovite during their growth.

The most distinctive feature of the silicis schists is the common and abundant development of muscovite. The most characteristic occurrence of this mineral is in small flakes which lie in great numbers along parallel or rhomboidal cataclastic zones and mosaic areas of albite and quartz containing minor amounts of epidote, clinozoisite and chlorite. These micaceous laminae produce the schistosity as well as outline augen and flaser of cataclastic relict minerals. Where more coarsely crystalline, muscovite tends toward a parallel arrangement. In finer textured areas small laths have a diverse, closely packed, almost dessucate habit. Muscovite commonly is about 0.02 mm. long but in some specimens is coarser grained to porphyroblastic. Many flakes are slightly bent and strained.

Accessories include pyrite, leucoxene, ilmenite, apatite, limonite, sphene.

Intermediate Rock Types: There is little gradation from the mafic rocks of the border zone to the silicic types developed in the central portion of the Hillabee sill. However, rocks of an intermediate type do occur (numbers 11, 12, and 13 in Table I.) Texturally, structurally, and mineralogically they more closely resemble the silicic schists than they do the mafic phase.

Field relations between the schist phases show generally a narrow to sharp transition zone. One of the best exposures, along Hillabee Creek in section 3, T. 21S., R. 6E., shows a gradation, in a distance of some 50 feet, from fine-grained chloritic schists into coarser-grained lighter gray schists having large hornblende porphyroclasts of diverse orientation. In the latter rocks, quartz-albite veins and stringers, some of which transect the schistosity at low angles, are prominent. These small injections seem to be confined to the schists of the transition zone and were not definitely recognized in the typical quartz muscovite schist nor in the border phase schists. (Figure 20.) Near Pyriton, however, the change in schist phases is quite abrupt. (Figure 21.)

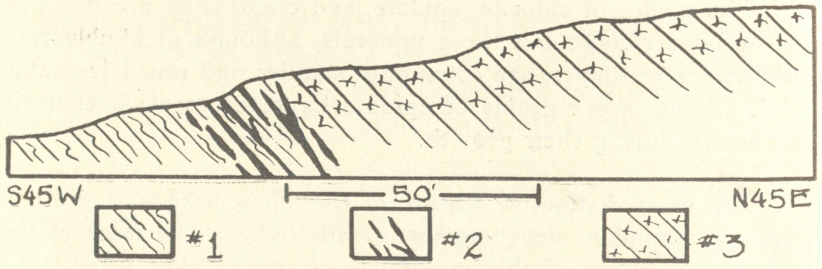

FIGURE 20

Figure 20. Section of Hillabee sill along Hatchett Creek showing relatively sharp contact between silicic and mafic phases of the sill. No. 1—Silicic schists; No. 2—quartz-albite veinlets and pods in silicic (or intermediate) schists; No. 3—Mafic schists. (Locality: SW ¼, Section 3, T. 21S, R. 6E.)

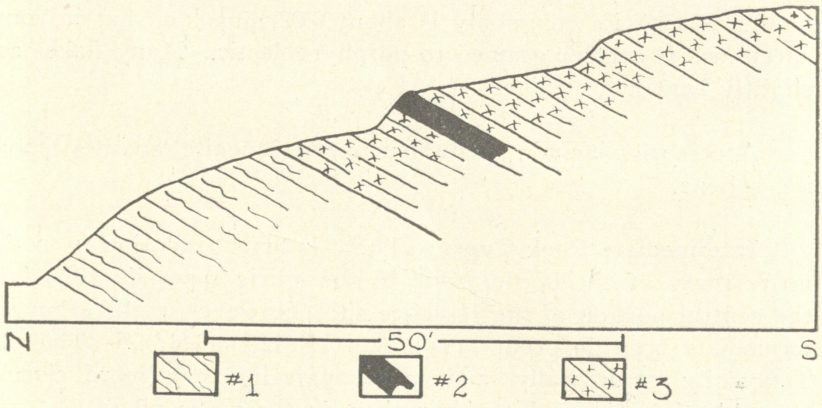

FIGURE 21

Fgure 21. Section of a portion of the Hillabee sill near Pyriton showing sharp contact between silicic and mafic phases. No. 1—Silicic schists; No. 2—Quartz-pyrite mineralization in mafic schists; No. 3—Mafic schists. (Locality: W central ½, Section 20, T. 19S., R. 8E.)

Microscopically the schists that are hosts to quartz-albite veins and stringers contain large amounts of muscovite and considerably more amphibole and epidote-clinozoisite-chlorite alteration products than the typical albite-quartz-muscovite schist. Veinlets or lens walls are somewhat angular and irregular because of detachment or partial separation of fragments of the host

rock. The introduced material is dominantly very coarse grained albite and quartz. All grains are strongly cataclastic and are bordered or surrounded by a narrow, schistose, finer-grained mosaic. (Figure 22.) A most prominent feature is the presence, in some portions of the veinlets, of innumerable needles of pale green amphibole arranged in a fluxion pattern parallel or sub-parallel to vein walls. (Figure 17.) These have no relation to twinning laminae in the albite. Some few amphibole needles show a bending or break in an underformed portion of feldspar or

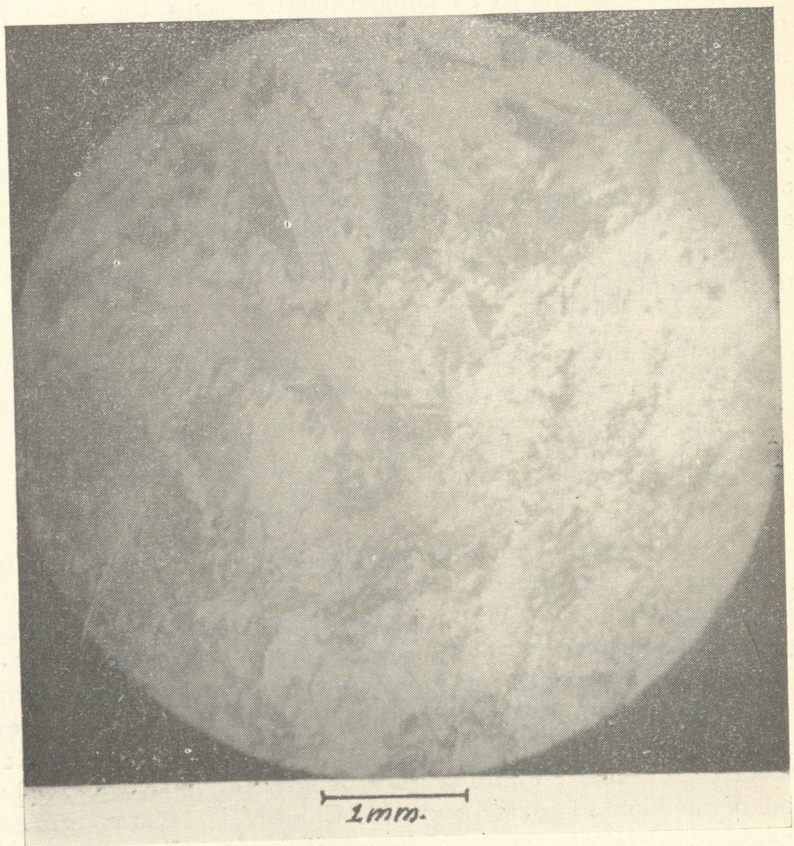

FIGURE 22

Figure 22. Photomicrograph of intermediate type of Hillabee schist. Quartz-albite-hornblende-muscovite schist with post-metamorphic quartz-albite veinlet. Veinlet has been strongly sheared and partly recrystallized. (Locality: SW ¼, Section 3, T. 21S, R. 6E.)

quartz but where these host grains are granulated or fractured there is an accompanying deformation of the inclusions. Epidote and clinozoisite are present locally and a little muscovite, along veinlet borders, may represent a wall rock contamination.

Extreme and Mineralized Types: There are developed in the border zone several unusual rock types. Among these are amphibolites or hornblende schists and epidote hornfels. Mode of amphibolite is shown in Table I, number 20. Lath shaped hornblende grains are up to 1.1 mm. in length. Cataclasis is not pronounced although the grains are locally bent and broken or even interpenetrating. A little clear albite is interstitial to amphibole.

The epidote rocks are of inequigranular subporphyroblastic texture. A little albite and very much bleached and shredded amphibole form a schistose fabric which is almost obliterated by an excessive development of epidote and clinozoisite ranging in size from very small granules up to blocky idioblastic grains more than 1.0 mm. wide.

Some of the epidotic rocks show a pervasive and fine grained alteration of the amphibole areas to epidote. There is also in such rocks a vein pattern parallel to or transverse to the schistosity. The veinlets are composed dominantly of coarse grained epidote and clinozoisite.

In many specimens of the several types of schists examined, shear patterns are superposed on the original fabric and along these there has usually been a moderate introduction of pyrite and quartz accompanied, generally, by the chloritization of amphibole or biotite. In several areas such mineralization has been intense and on such a scale that the resulting quartz pyrite veins and quartz pyrite chlorite schist have been mined.[35] The schists adjacent to the quartz-pyrite ore are of moderately schistose fabric and of medium to coarse texture. Chlorite is coarse grained, xenoblastic, and abundant; it frequently is set with slightly deformed cleavages transverse to the schistosity. A poorly schistose equigranular granoblastic mosaic is formed by quartz and a

[35]For a description of mining history and properties, see Prouty, W. F., op. cit., pp. 79-83.

little albite. The fabric is strained and fractured and chlorite is deformed by idioblastic pyrite grains up to 1.8 mm. in size. Considerable amounts of idioblastic sphene are present, generally enclosed in chlorite.

IGNEOUS ORIGINALS OF THE HILLABEE SCHIST.

The conclusions of previous workers that the Hillabee schist is a metamorphosed igneous intrusive are abundantly substantiated by the present investigation. Few specimens were examined in which igneous textures were wholly preserved. Yet, in some, the only alteration seems to have been a slight mortaring of plagioclases and, possibly, a recrystallization of the original pyrabole to biotite leaving, as a relict, a cataclastic diabasic texture.

Supporting evidence of the original igneous nature may be found in bulk mineralogical composition and in the preservation, as cataclastic relicts, of minerals of magmatic origin. Of these latter, the best are the amphiboles—hornblende and paragasite—and albite. Some of these minerals are of such large size as to suggest their original nature as phenocrysts. The amphiboles have usually round inclusions of apatite.

Additional evidence of intrusive origin is found in the relation of the Hillabee schists to bordering rocks. This will be considered in a following section.

Estimation of the original rock types from which the various schists have been derived is largely conjectural. Ignoring the possibility of considerable addition or subtraction of certain substances during metamorphism, such an estimate may be made on the basis of metamorphic modes recalculated to magmatic mineral species. Here is encountered the problem of the nature and history of the plagioclase and of the precise deriviation of such metamorphic minerals as muscovite, the epidotes and chlorite.

Plagioclase is universally present in the several schist types of the Hillabee sill. Petrographic examination of 64 thin sections has shown that all plagioclase, igneous relicts as well as granoblastic grains, has the composition of albite. Becke[36] has stated

[36]Beckit, F.—Ueber Mineralbestand und Struktur der Kristallin'schen Schiefer, Denkschr. k. Akad. Wiss. Wein, Vol. LXXV, 1913, pp. 42-43.

that albite is the characteristic form of plagioclase under conditions of strong shearing stress, while anorthite is anti-stress. Harker[37] indicates that cataclasis of the plagioclase feldspars is accompanied by saussuritization—the sodic components recrystallizing as clear albite granules, the calcic giving rise typically to zoisite and epidote. Wiseman[38] records the characteristic presence of albite in certain low grade epidiorites in the south-west Highlands of Scotland but cites several other areas in which intermediate and basic plagioclase have been sheared and crushed with little or no change in composition, although associated hornblende had been altered to chlorite.

Evidence of the albitization of the plagioclase feldspars as a consequence of cataclasis of a more calcic plagioclase is not conclusive.

There is no clear-cut evidence in the Hillabee sections examined that the epidotes result from the saussuritization of calcic plagioclase, as Harker suggests. In the chlorite-epidote schists of the Hillabee sill the epidote minerals show a strong affinity for the amphibole and it is suggested that they have been derived very largely from this mineral. The possibility that material has been added from the plagioclase during this process cannot, however, be ruled out.

Finally, it must be pointed out that the preservation of porphyroclasts of igneous albite suggest that the original feldspar was of this composition. This, however, is at variance with the few relic igneous structures which are of diabasic character and which might be taken to imply an original plagioclase having the composition of andesine or oligoclase. Furthermore, it may imply either a spilitic rock or one that had been albitized prior to metamorphism by igneous emanations.

Epidote, clinozoisite, and chlorite are thought to have been derived primarily from the constituents of the amphiboles and biotite; muscovite is ascribed to original orthoclase.

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[37]Harker, A.—Metamorphism, Methuen & Co., Ltd., 1932, p. 174.

[38]Wiseman, J. D. H.—The Central and Southwest Highland Epidiorites: A Study in Progressive Metamorphism Quart. Jour. Geol. Soc. London, 1934, pp. 398-399.

Assuming that these mineralogical transformations did obtain during metamorphism, the original of the quartz muscovite schist type might be characterized as a silicic rock with abundant quartz and silicic feldspar, dominantly albite, and with minor amounts of hornblende and accessories. An original rock of granodiorite or quartz diorite affinities, but with albite instead of a more basic plagioclase, is suggested.

The chlorite-epitote-hornblende schists probably were derived from a mafic rock with abundant pyrabole or biotite and, generally less than 50% quartz and silicic feldspar. Presence of rocks in the border zone composed originally dominantly of ferromagnesium minerals may indicate special magmatic conditions. It is suggested that an original intrusion of a rock resembling an albitic quartz-diorite was followed, after crystallization was nearly complete, by a filter-pressing and at least local and partial straining off of the residual and more silicic portions of the magma, producing a somewhat more mafic rock than the original magma would have formed if completely crystallized. This process probably was followed closely by a renewal of intrusion—the latter being responsible for the more silicic types occurring centrally in the sill.

METAMORPHISM:

The intrusion of the Hillabee sill was followed by effects of a metamorphic nature which altered or obligated igneous structures and textures and which gave rise to new mineral assemblages. These features as developed in the Hillabee schist are similar to those developed during the course of normal progressive regional metamorphism of low grade affecting igneous rocks of intermediate to silicic composition.[39] Physical conditions generally inferred for such adjustments are low temperature and strong shearing stress.

It is considered probable that the earliest and most intense efforts of shearing stress were on the border rocks of the Hillabee sill. Quartz and albite were granulated, as attested by cataclastic albite relicts, and amphibole grains were broken and strained. Temperatures were soon reached, however, at which quartz and albite, though not the amphibole, yielded to deformation plastically

[39]Harker, A., op. cit., pp. 152-177, 271-297.

by recrystallization. This is evident in the subporphyroblastic, granoblastic, and schistose modes of these minerals. The effect of such widespread recrystallization on the amphibole was the development of a parallel or subparallel orientation by rotation. A measure of the extent of plastic deformation is recorded in the spreading of amphibole cleavages and in the "floating" away of trains and swarms of acicular cleavage fragments.

Structural rearrangements in the silicic, centrally located rocks, seem to have lagged somewhat behind those of the border rocks. Cataclasis—the microbrecciation of the fabric—is commonly extreme but the recrystallization that marks a higher grade of metamorphism is not well developed. Except for mineralogical differences and the lagging mentioned there seems to be no real differences in the metamorphism of the silicic and mafic rocks. Certain, probably restricted, areas of each type appear to have been shielded from shearing stress. Rocks in these areas show some cataclasis but are essentially unmetamorphosed.

Mineralogical transformations that have attended structural alterations of rock fabric show no new or unusual features. Muscovite was produced from orthoclase after granulation and strewing. The degree of development of this mineral is reflected in the character of its associated quartz-feldspar. Where imbedded in a cataclastic and partly recrystallized fine-grained fabric, muscovite is subidioblastic and of small size. Where it occurs, however, in association with recrystallized quartz-albite of coarser-grained granoblastic mosaic or schistose habit, grains are large and more nearly idioblastic.

Epidote and clinozoisite show, in many specimens, a striking affinity for the amphibole which they rim and apparently replace. These minerals enclose biotite, have thrust aside muscovite during their growth, and have been locally fractured with openings healed by albite. it is suggested that minerals of the epidote group probably derived the major portion of their composition from the amphibole.

Chlorite appears to be related mostly to a later stage of metamorphism and may be regarded as of retrograde nature. Its substance probably was derived largely from amphibole or biotite.

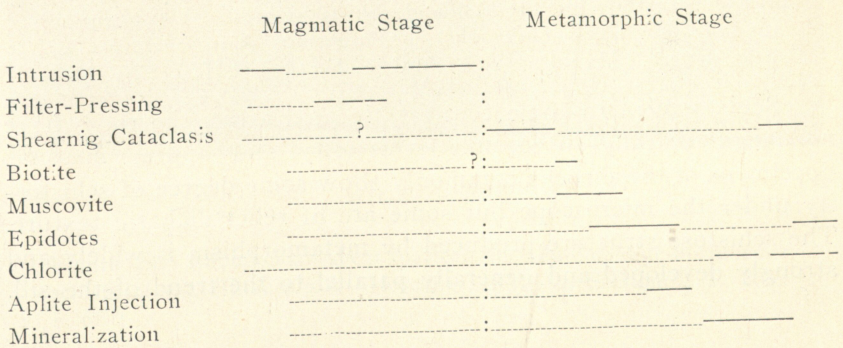
Its frequent association with pyrite, carbonate, and quartz is indicative of alteration accompanying mineralization or hydrothermal action.

That the course of metamorphism in the Hillabee schists was of intermittent and probably interrupted nature is suggested by the quartz-albite injections in certain intermediate types of schist. These were later than the major metamorphism for they include fragments of muscovite, epidote, and clinozoisite. They are themselves strongly cataclastic indicating a renewal, following their injection, of regional shearing stresses.

A metamorphic feature of later stage is recorded in the extensive quartz-pyrite mineralization of the mafic schists and by a fine textured epidotization and epidote-veining of some of the schists. These processes are essentially of hydrothermal and mineralizing character.

The presence of biotite is rather anomalous and difficult to explain. Both brown and green varieties are present. Felted aggregates of small brown laths are common, as are green varieties which are intimately associated with muscovite and the epidote minerals. Biotite may owe its origin in part to late magmatic changes of a deuteric nature. Some seems definitely to have originaed at the same time as muscovite and probably was derived from horneblende.

A schematic summation of conclusions regarding the magmatic and metamorphic history of the Hillabee sill is shown in the following diagram.



STRUCTURE.

Marginal Relations: The schistose structure of the Hillabee rocks is generally conformal with the sill boundary. Although the intrusive nature of the original Hillabee rock is proven—by relict microscopic textures and minerals and by the field evidence of sill-like apophyses of the Hillabee in bordering rocks as well as large inclusions of these latter in the Hillabee—the contact is nowhere clearly intrusive in appearance. (Figure 23.) The mafic border-zone schists become finer-grained, strongly corrugated, and wrinkled near the contact, which usually is obscured by a deeply weathered zone from five to ten feet wide. In some areas the schistose structure of the Hillabee is discordant with both the contact and the schistosity of adjacent rocks. It is considered that the original instrusive nature of this feature has been obscured by metamorphism and by cataclasis, folding, and faulting.

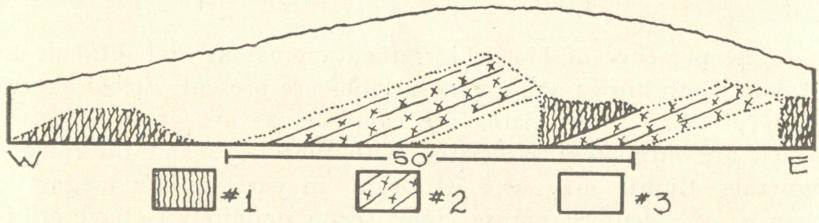


FIGURE 23

Figure 23. Section showing small injections of the Hillabee present in the Ashland formation. No. 1—Ashland schists; No. 2 Hillabee schists; No. 3—Bedrock concealed. Schistose structure of the Ashland formation is vertical and is transected by a later shear pattern which dips N 50 W at angle of 70 degrees. Ashland is locally a phyllite mylonite but Hillabee is an albite-epidote-hornblende schist. Discordance of planes of Hillabee intrusion with any present structures of the Ashland schists suggests that intrusion was localized along fault plane of later age than schistosity or shear pattern. (Locality: N Central ½, Section 29, T. 21S., R 7E.)

Schistosity: In some centrally located areas, the rocks have no megascopically discernible schistosity and appear massive. Specimens of these rocks commonly show some degree of schistosity under the microscope but some are of relict diabasic texture. The schistose structure produced by metamorphism is widely and strongly developed and generally parallel to the trend of the sill.

However, over large areas there are gentle folds and changes in dip related to post-metamorphic regional deformation. Locally, the schists show a secondary and well developed large-scale rhomboidal shear pattern. (Figure 24.) Some are faulted and slickensided.

Pattern: The discontinuous, attenuated, and arcuate pattern of the Hillabee sill is related to its locus of intrusion. It has already been noted that the sill was injected along the plane of the Whitestone fault. The major movement along this fault had occurred prior to intrusion is indicated by the fact that the Hillabee encloses large tabular masses and partly engulfs wedge-like projections of strongly sheared and locally mylonitized Ashland schists and of sheared, silicified Talladega phyllites. On the other hand, post-intrusive regional stresses of intermittent character metamorphosed the intrusive rocks, and, following this, resulted in large scale gentle folding and a renewal of overthrusting involving all three formations. The Hillabee sill, then, is clearly of syntectonic nature.

FIGURE 24

Figure 24. Rhomboidal shear pattern in albite-epidote-hornblende schists of the Hillabee sill. (Locality: NW ¼, Section 1, T. 20S., R 6E.)

Relative to the character of the Whitestone fault, the regionally undulatory nature, or fluting, of this plane has been described. Movement of the Ashland thrust block northwestward along such an uneven surface must have tended to create open spaces of lenticular character. In the normal course of overthrusting such spaces would not be formed on large scale, for collapse, folding, and faulting would tend to close such zones as they developed.

The intrusion of the Hillabee sill, therefore, is believed to have been concommitant with a period of overthrusting. As large open spaces, produced by thrusting along a surface of discontinuity, began to form they were filled by the upwelling of Hillabee magma under sufficiently great pressure to prevent more than a partial collapse of the overriding thrust block. The major portion of the sill is confined, thus, to the actual plane of the Whitestone thrust; local intrusions occupy smaller spaces opened along subsidiary faults in adjacent formations.

Metamorphism of the sill was followed by a continuation of regional folding and overthrusting. The effects of this diastrophism are recorded clearly in major structural discordances in the area between Hollins and Millerville. Here the deformation indicates a general northeast southwest compression of the sill, accompanied or followed by northwestward thrusting of the Ashland schists over the sill.

Portions of the Whitestone fault where the Hillabee schists are absent may have resulted from a faulting out of the formation. They are believed, however, to represent bearing surfaces where no intrusion occurred.

AGE OF THE HILLABEE SILL.

The Hillabee sill intruded rocks of upper Paleozoic, probably Pennsylvanian, age. Its intrusion was largely localized along a fault that intersected strata of known Pennsylvanian age. Intrusion occurred during the actual overthrusting. Overlapping the Hillabee schists on the south are the unmetamorphosed sands and gravels of the upper Cretaceous Tuscaloosa group. The intrusion and subsequent metamorphism of the Hillabee rocks, therefore, is assigned to the major orogeny ending the Paleozoic Era—the Appalachian Revolution.

EVOLUTION OF REGIONAL STRUCTURES

Structural features of the Talladega and Ashland decken have been described in preceding sections. Dominant elements are the northeasterly trace of the Whitestone fault and the general southeasternly dips of bedding and schistosity. Superposed on and deforming this regional pattern are eastward plunging folds and systems of east-west and north-south thrusts.

The major features of structure, plus the intrusion and metamorphism of the Hillabee sill, belong to the Applachian Revolution. There remains, then, the problem of the age and origin of the secondary structures.

The two areas of most pronounced subsidary disturbance are in the north, near Pyriton, and in the south, near Hollins, Elias, and Millerville. In the vicinity of Pyriton the bend of Talladega Mountain toward the west is marked by an imbrication of the quartzites due to westward thrusting along north-south trending faults. The most easterly of these passes southward into an anticline and the structure may entirely disappear farther down dip. Some of these structures may be traced up to the Whitestone fault but involve neither the Hillabee sill nor the Ashland formation. This is presumptive evidence that these subsidiary structures originated prior to the development of the Whitestone fault and the intrusion of the Hillabee magma. Stresses responsible for these structures seem to have been directed westward rather than northwestward.

Farther south in the Hillabee map area lies a broad east-west trending zone of disturbance which involves all three formations. The easterly plunging anticlinal character of this zone is indicated by the bend in the Cheaha quartzites near Bull Gap. Eastward from this point the higher phyllites of the Talladega define two faulted anticlinal prongs, one extending toward Eilas, the other toward Millerville. Between these lobes there projects, from the east, a wedge of intricately folded and faulted Ashland schists. Northwest of Millerville the nature of the deformation is recorded by a bending toward the southeast of the regional Ashland schist structure.

The fluted character of the plane of the Whitestone fault has been mentioned. Near Millerville and Elias the fault plane rises to its highest stratigraphic horizon within the Ashland formation. In the adjacent phyllites of the Talladega series, its change of horizon within short distances is marked. It is considered that this characteristic of the Whitestone fault defined a zone of weakness which yielded readily to northeast-southwest compression.

Structural deformation was advanced in this area before the intrusion of the Hillabee sill. Proof of this lies in the fact that the Hillabee is less deformed than the enclosing formations. The deformation of the Hillabee, however, is itself evidence of post-intrusive renewel of north-south compression.

The structural relations set forth above indicate that compressive stresses acting at considerable angles (about 45°) to the major regional stresses both preceeded and followed the intrusion and metamorphism of the Hillabee sill. The sill is syntectonic; its emplacement was preceded by major overthrusts; it was intruded during a period of actual thrust movement; and, it was followed by stresses which caused its metamorphism and which were responsible for additional overthrusting. These relations indicate, therefore, that the north-south compressional stresses were contemporaneous with the major northwestward forces of the Appalachian orogeny.

The origin of the subsidiary compression is unknown. Compressional features similar to those described herein, but of lesser magnitude, have been shown by Rich[40] to result from a wedging along diagonal faults of segments in a thrust block. If such diaognal faults are present in the Hillabee map area, they have not been recognized. Similarly, certain portions of an extensive thrust sheet may have dragged behind because of locally greater obstruction to thrust movement. Such drag would result in a compression in the lag areas but would just as surely result in tensional forces in the more advanced parts of the sheet. Structures of tensional origin appear to be lacking in the Hillabee area.

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[40]Rich, John L.—Mechanics of Low-Angle Overthrust Faulting as Illustrated by Cumberland Thrust Block, Virginia, Kentucky, Tennessee, Bull. A. A. P. G., Vol. 18, 1934, pp. 1584-1596.

SUMMARY AND CONCLUSIONS

Rocks of the Hillabee map area belong to three groups: (1) the Mesozone garnetiferous and graphitic quartz-muscovite and quartz-biotite schists of the Ashland formation; (2) the epizone quartizites, sericite and chlorite phyllites, and graphitic slates of the Talladega series; (3) the quartz-albite-chlorite-epidote-hornblende schists and quartz-albite-muscovite schists of the Hillabee sill.

The age of the Ashland Mica Schist is unknown. It is assigned to the pre-Cambrian by the U. S. Geological Survey but may be Paleozoic. The upper part of the Talladega series contains fossils of Pennsylvanian age in the Erin slate; stratigraphically lower beds —the Cheaha quartzites—are tentatively correlated with the Devonian Butting Ram (?), Jemison, Yellowleaf sequence further south in Alabama.

The Talladega series and the Ashland Mica Schist occur in extensive overthrust wedges or decken separated by the Whitestone fault. During a period of thrust movement the Hillabee sill was injected into spaces opened along the irregular plane of overthrusting. A renewal of regional stresses following intrusion resulted in metamorphism of the igneous body under epizone conditions, and in its subsequent deformation. Metamorphism, possibly excepting that of the Ashland schists, structural deformation, and intrusion were events of the Applachian revolution.

Igneous origin of the Hillabee schists is indicated by (1) its sill-like form and marginal injection of associated rocks; (2) presence of large included masses of adjacent formations within the Hillabee schists; (3) occurrence of relict diabasic textures; (4) presence of abundant cataclastic relicts of igneous albite and amphibole. Original rock types were probably of quartz diorite-granodiorite affinities but contained albite instead of intermediate plagioclase.

Metamorphism of the Hillabee sill was largely a response to strong regional shearing stresses acting on rocks at low and increasing but not extreme temperatures. Stresses, probably of intermittant character, affected border-zone rocks first. The course of metamorphism is marked by cataclasis of all constituents followed

by recrystallization of quartz-albite. Amphiboles show a strong alteration to the epidote minerals and to chlorite. Muscovite is abundant in the centrally-located schists; biotite is of sporadic occurrence. Metamorphism was followed by moderate shearing, regional folding and local faulting, and by quartz-pyrite mineralization.

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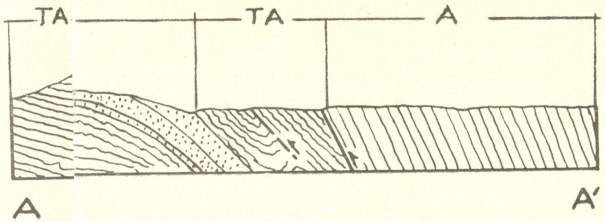

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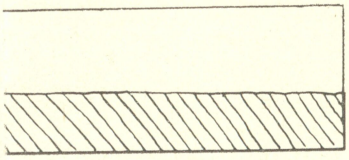

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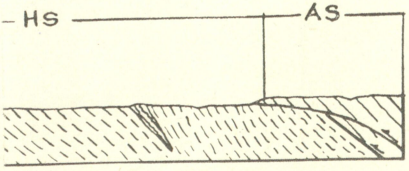

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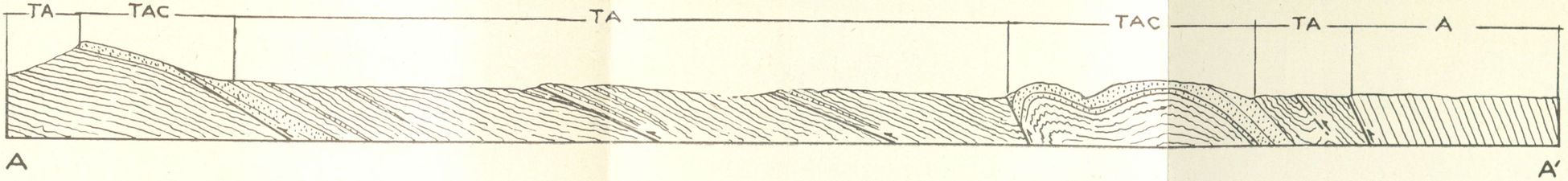

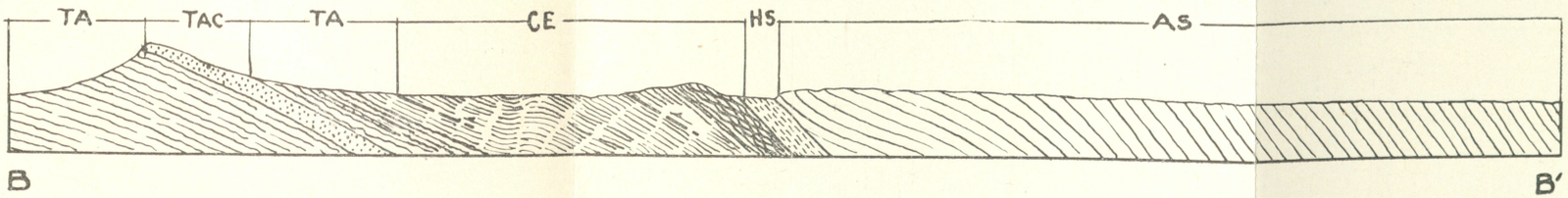

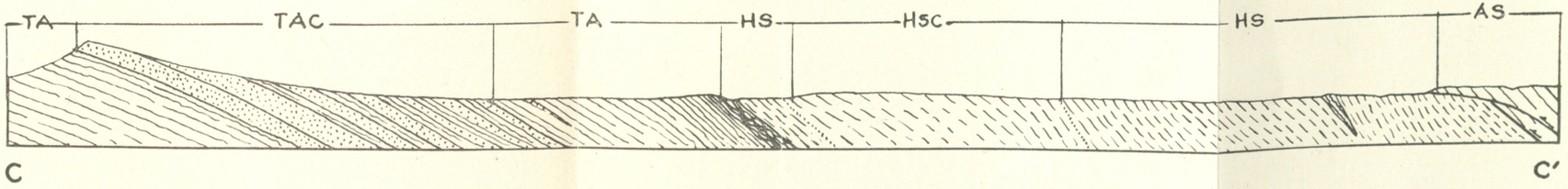

CROSS-SECTIONS TO ACCOMPANY GEOLOGIC MAP OF A PORTION OF THE HILLABEE SILL, TALLADEGA SERIES, AND ASHLAND MICA SCHIST, ALABAMA

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SCALE FEET

FOR LEGEND, SEE GEOLOGIC MAP.